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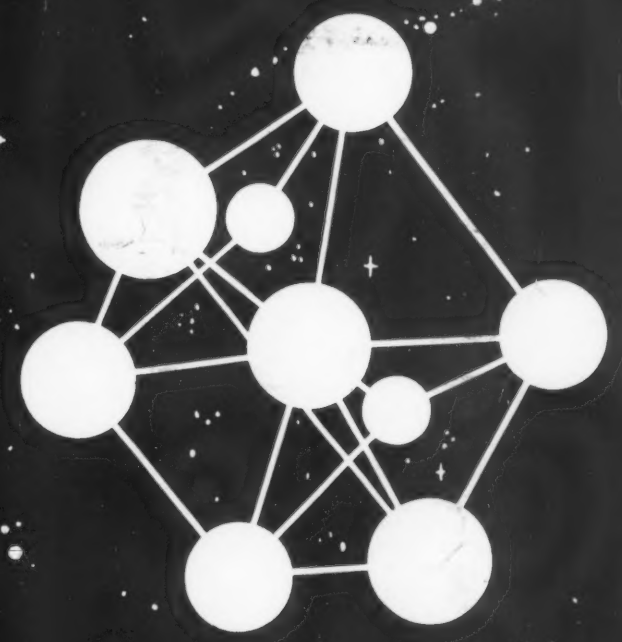

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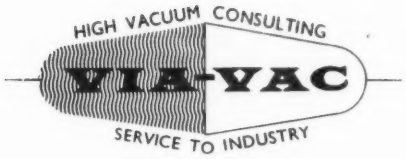

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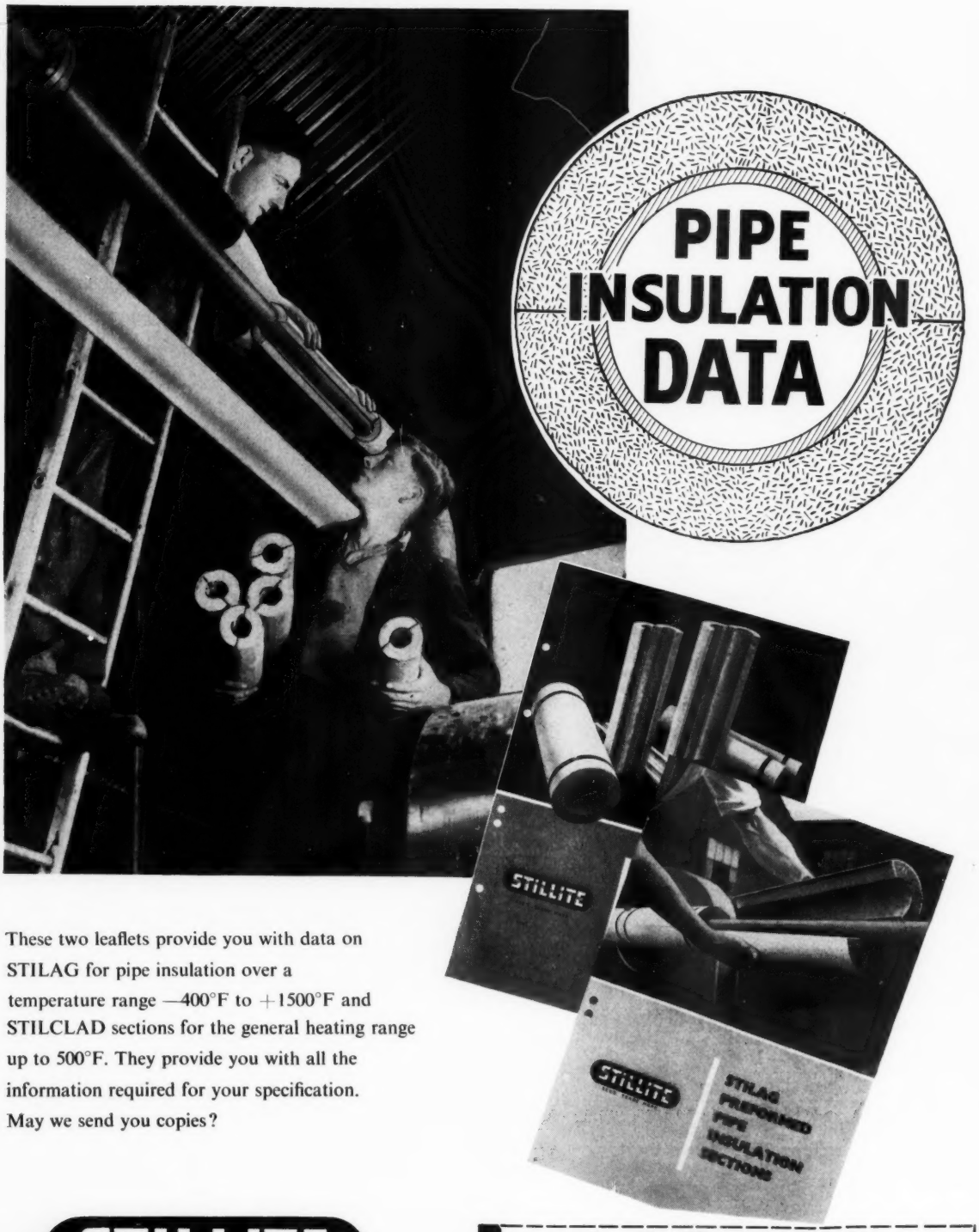

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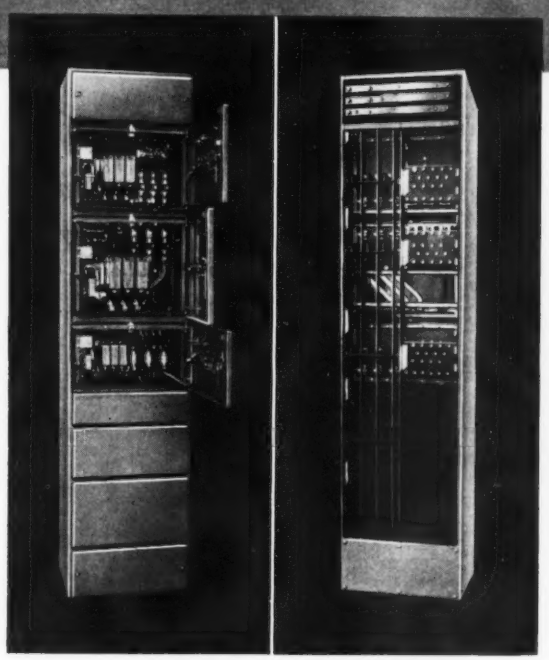

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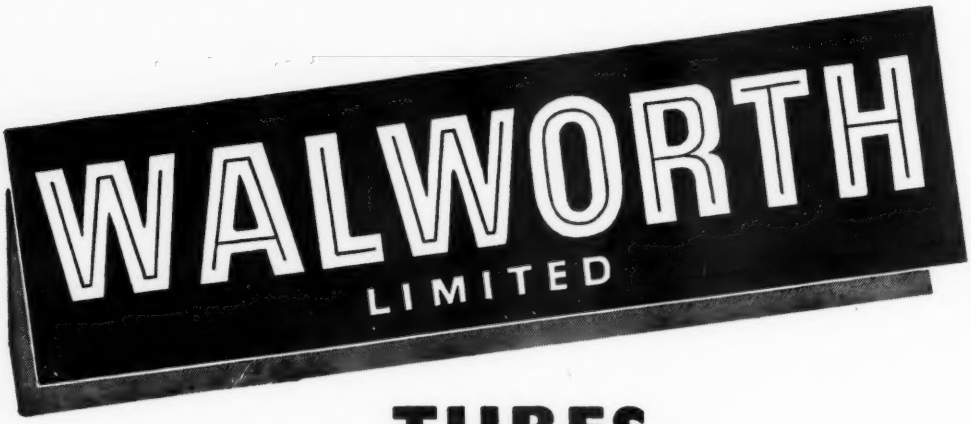

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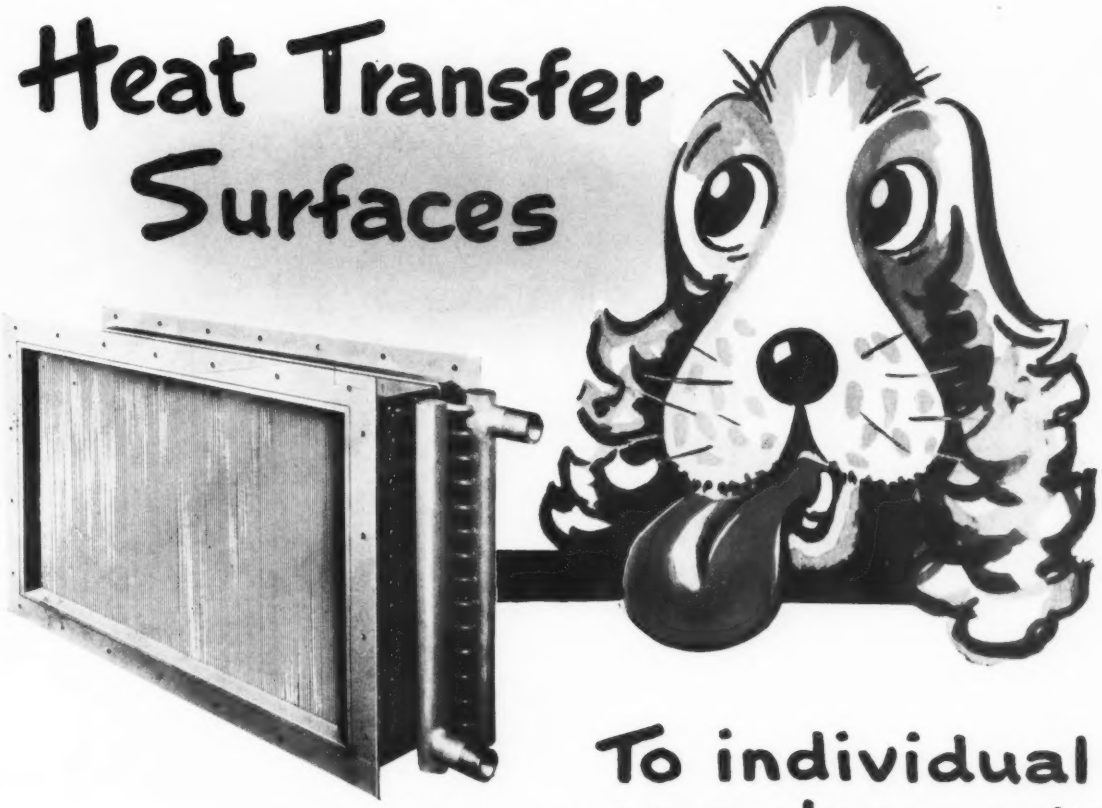

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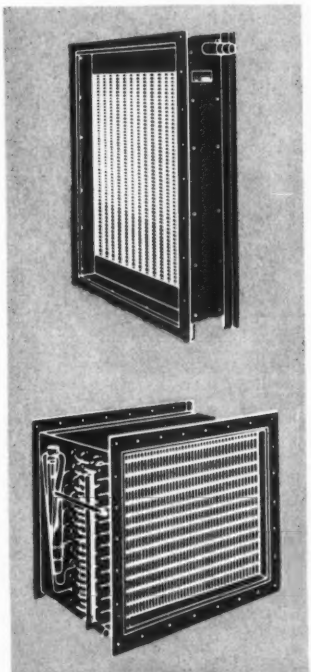

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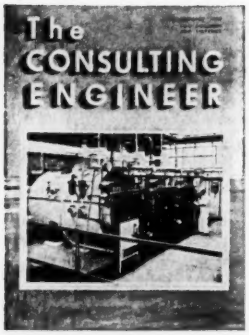

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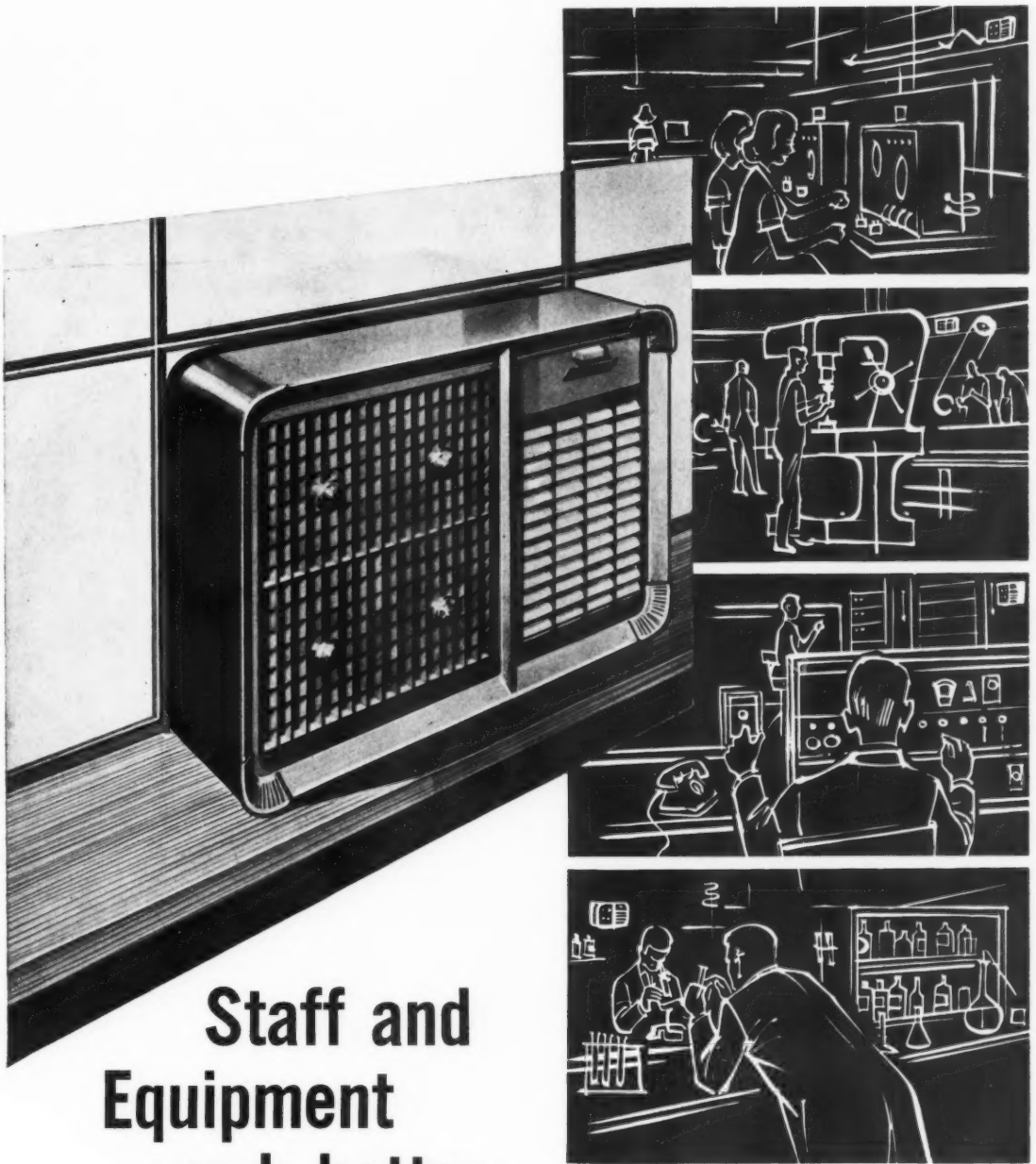

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JULY 1961

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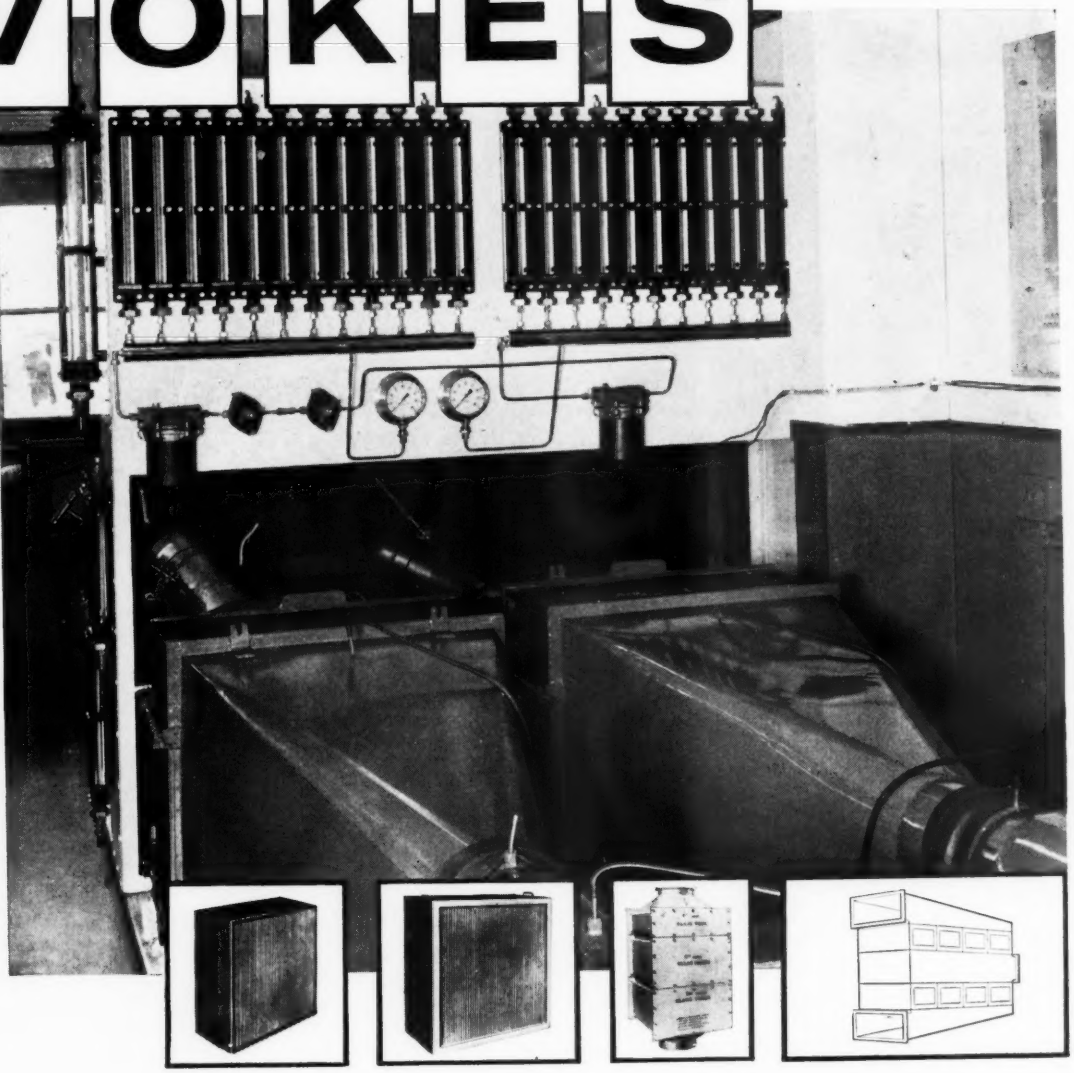

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Balloons Over Mildura

by John Loughlin

AIR samplings obtained by a series of upper air probes from a base in south-eastern Australia are helping United States and United Nations agencies maintain a global watch on radiation levels in the upper atmosphere.

Five times a month, samples taken with balloon-borne filters are being sent to the U.S. Atomic Energy Commission for analysis to detect the presence of fallout and radioactive materials.

The current series of stratospheric samplings, financed by the Atomic Energy Commission, began last December and will be continued at least until July.

By agreement between the U.S. and Australian Governments, a base for this work has been set up at Mildura, in the State of Victoria. The base was manned initially by a joint team of American specialists and experts from the Australian Department of Supply, but the Australians quickly mastered the complex techniques for launching the balloons, ranging from 48 ft to 90 ft in diameter and have now taken over the operation entirely.

" Operation Hiball "

The balloon probes, called " Operation Hiball," are linked with a separate upper air sampling programme, also based in south-eastern Australia, which the U.S. Air Force launched last October. For this programme three U2 reconnaissance aircraft and four JB57s operating from the East Sale air base in Victoria, flew on air sampling missions to within 100 miles of the Antarctic continent.

According to a statement issued by the Australian Minister for Supply, Mr. Athol Townly, at the time, the object was to detect the existence of plutonium, strontium-90 and caesium-137, all of which were considered potentially hazardous. The analyses would also detect strontium-89, cerium-144 and tungsten-185, which are useful in estimating the age of atmospheric debris.

UN Studies

Information gained by examining material trapped by the filters in the U.S. Air Force missions and " Operation Hiball " will be published, and will contribute to studies by the Scientific Committee of the United Nations in this field.

United States and United Nations agencies would no doubt be anxious to throw light on a number of aspects of the radiation problem in the southern hemisphere already investigated in the northern hemisphere by the more extensive monitoring facilities established there.

H-bomb tests

In their sampling for fallout, two questions would seem to be in mind. One is what, if any, radioactive debris survives in the atmosphere from the British atomic tests carried out in the southern hemisphere. The first of these was at the Monte Bello Islands, off north western Australia, in 1952 and further tests were staged in 1956 at Monte Bello, and at Maralinga base, on the southern Australian desert near Woomera. One other British device, an H-bomb, was exploded in May, 1957, at Christmas Island, in the Central Pacific just above the equator.

A further question that arises is whether fallout from the many tests carried out by the United States and the Soviet Union, and more recently by France, has found its way into the great air circulation systems and the less known upper air streams of the southern hemisphere.

The balloon has been launched. The instrument pack can be seen below the balloon, on the ground is the lorry which helped in the launching

Presumably, when the results of the studies of the air sampling programmes are made public, they will answer some of these questions.

Meanwhile, the most recent report (for 1959-60) of the National Advisory Committee, a group of Australia's foremost scientists, is of interest. The committee concluded that during 1959 the increase in fallout levels in Australia from nuclear weapon tests was one-tenth the increase of levels in the more densely populated regions of the northern hemisphere. Fallout levels stood at about a fifth to a quarter of those in the northern hemisphere and the committee commented that allowing for the most pessimistic set of assumptions, the radiation risks faced by Australians from fallout were insignificant compared with the " normal daily hazards of life."

The task assigned to the U.S. Air Force team based on East Sale was to air test at different altitudes

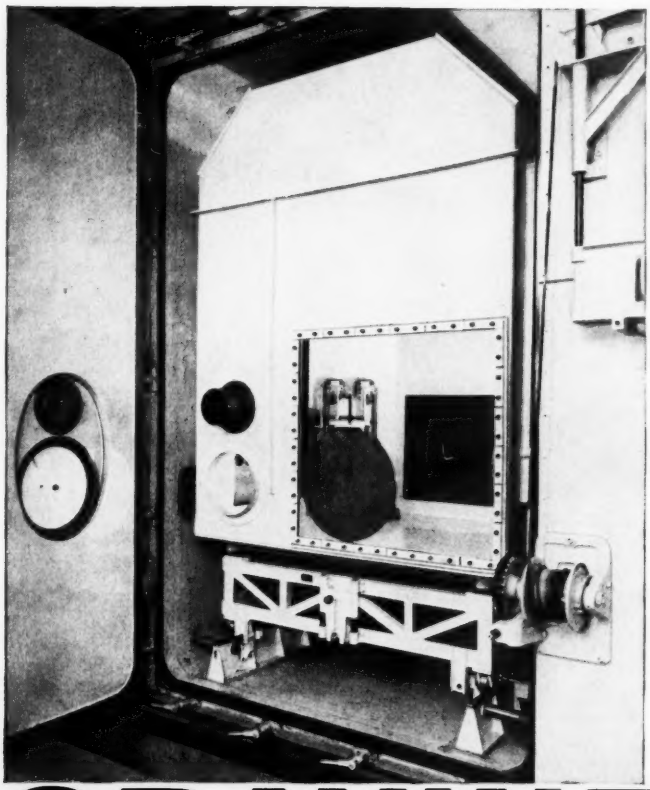

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Illustration: Hot Cell Alpha Box.

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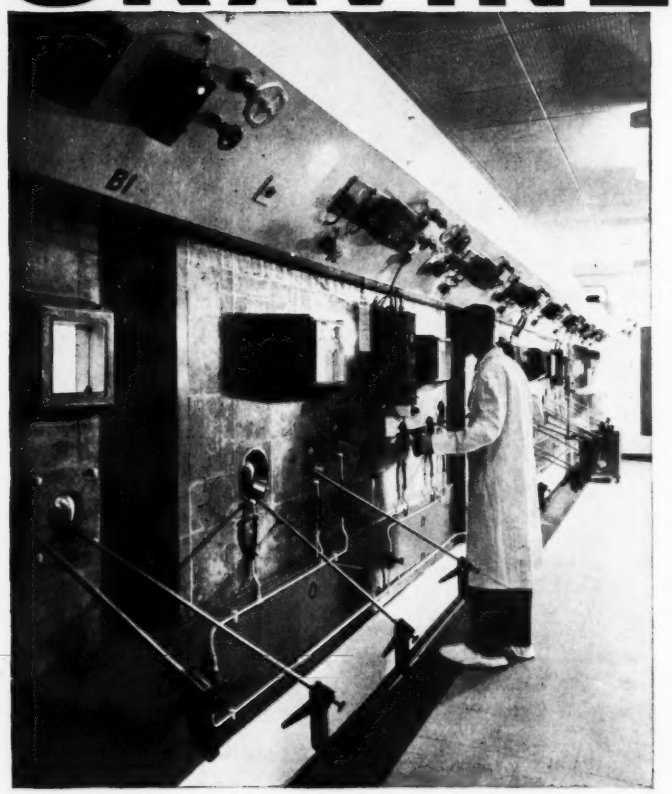

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Illustration: a heavily screened bench, for chemistry with radioisotopes.

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over the landless ocean region extending to the Antarctic continent. Modified twin-jet JB57s were able to take samplings at altitudes of up to 40,000 ft while the high-flying U2s could operate at least up to 70,000 ft.

On the other hand, the unit based at Mildura is able to send up its balloon-borne sampling devices at frequent intervals over an initial period of about eight months to altitudes of up to 90,000 ft beyond the reach of manned aircraft.

For its current requirements, the U.S. Atomic Energy Commission is maintaining only two such sampling stations—the one for the northern hemisphere is located at San Angelo, Texas.

Balloon prepared for launching. The vehicle on the left is carrying the instrument load and will move forward under the balloon on launching so as to avoid any undue stress

Climate

Factors which dictated the choice of Mildura were the suitability of its climate for consistently successful balloon launchings and the flat open terrain over a wide radius which facilitated the recovery of the payloads of instruments.

Mildura is in the 10 in. annual rainfall zone, but it is located on the banks of Australia's greatest river, the Murray, and irrigation systems founded over 70 years ago by the Californian brothers, George and William Chaffey, have transformed the once arid area into an oasis of vineyards and citrus groves.

Four American specialists from the firm of General Mills, Inc., contractors to the U.S. Atomic Energy Commission for the manufacture of the polythene balloons and sampling devices, arrived in Australia last November.

With the Australian Department of Supply team of 10 they set up the base at Mildura Airport where suitable buildings and an established meteorological station were available. They launched their first balloon, 48 ft in diameter, to an altitude of 48,000 ft on December 18th.

The effectiveness of the whole programme depends to a large extent on a highly efficient up-to-the minute meteorological prediction service. The launching crew must know in advance that conditions will be suitable for a launch, for the ascent, for the floating and air testing stage and the subsequent recovery of instrument payload.

Before the dawn launching the station operated by the Bureau of Meteorology maintains a constant watch on surface and upper air conditions. A special picturegram unit on the spot receives the latest weather charts from Melbourne compiled from data recorded at weather stations all over Australia. Weathermen at Mildura, track meteorological balloons sent aloft to show what variations in wind direction exist at various altitudes.

The launch

Armed with this information, the balloon team plots the anticipated trajectory of the balloon before launching, and the ground recovery party is already planning its recovery operation. The surprisingly complicated launching procedure is clearly the result of much trial and frustrating error. The careful unfolding of the balloon bag as it is fed between restraining rollers and fills with helium, the meticulous deployment of the suspension harness of nylon upwind to the instrument payload mounted on a launching vehicle, the sudden climax as the balloon is released and the vehicle rushes beneath it to release the payload without sudden stress, are all part of a well rehearsed performance. Then the balloon floats serenely upward with its gently swaying 350 lb load of sampling filters, batteries, air pumps and motor, and equipment to record and transmit data on altitude, atmospheric pressure, and volume of air intake. With it go sets of emulsified photographic plates to record variations in cosmic radiation for Melbourne University's Department of Physics.

Once the balloon becomes airborne it is tracked by a ground beacon and followed by a light aircraft equipped with direction finding equipment, and linked by radio with the ground station and the ground recovery party.

At the appointed altitude the air pumps automatically begin drawing in air through the filters. Sampling continues at level flight for 30 to 40 minutes. Then the motors automatically switch off, and the instrument payload is released and drifts slowly to earth by parachute, closely observed by the spotting aircraft.

Most of the landfalls in "Operation Hiball" have occurred in the region of 100 miles from the control station, but in one 89,000 ft flight, the recovery team had to travel over 400 miles to reach the instruments.

Up to mid-February the "Operation Hiball" team had achieved the creditable record of 100 per cent recoveries, thanks to the favourable terrain, excellent meteorological services and as they put it, "a little bit of luck." △△△

HALDEN REPORT

THE Steering Committee for the Halden (Norway) Boiling Heavy Water Reactor Project has recently published the Second Report on the Project. The reactor first achieved boiling in October, 1960.

The First Report covered the preliminary period of joint operation and was presented to the ENEA Steering Committee in November, 1959. The Second Report now published covers technical progress from November 1st, 1959 to December 31st, 1960 and also gives a full detailed description of the reactor installation and the general administration of the Project. △△△

Classroom and Laboratory

Arising out of a proposal by Dr. F. R. Paulsen, at a Council Meeting of the Institution of Nuclear Engineers, several hundred teachers of nuclear science were asked to report on simple apparatus and methods used or those which might be useful for practical demonstrations in instructional courses. The response was enthusiastic. From all parts of the world, from teachers in Universities, High Schools and Colleges, from research workers, manufacturers and public relations experts, have come many ideas. As a service to teachers, and also to other workers in nuclear fields, we are now publishing the many suggestions put forward. Each suggestion carries the identity of the person who put it forward, and also a reference number. The latter will facilitate enquiries sent in by readers requiring further information. Readers are invited to submit suggestions for inclusion in this feature

No. 54 An experiment on particle scattering

Dr. William Bertozzi and Dr. P. T. Demos, U.S.A.

In this experiment which illustrates particle scattering, hardened steel balls are shot at a hardened steel cylinder in a plane perpendicular to the axis of the cylinder. Each ball bounces off the cylinder and strikes a piece of paper, leaving an indentation whose position enables us to determine the scattering angle θ through which the ball has been deflected. From measurements of θ, the impact parameter b, and the radius of the ball, together with certain assumptions about the scattering process, the radius R of the cylinder may be found. Thus, the size of the cylinder is measured indirectly by observing the angular distribution of the scattered balls. The experimenter can compare his results with prediction based on specific assumptions about scattering, and can arrive at definite quantitative conclusions about scatterers. Some of the most interesting and significant results are obtained when the scattering is not elastic, and energy is transferred to the scattering particles in such a way that it reveals details of their internal structure.

In the diagram the ball shown is just colliding with the cylinder. The line LL' is parallel to the tangent to the cylinder at the point of contact. Assuming frictionless and elastic collisions, the angles $\beta'\beta''$ made by the initial and final velocity vectors with LL' are equal, then:

$$\beta'=\beta''=\theta/2. \quad . \quad . \quad . \quad \text{(i)}$$

The scattering angle θ and the impact parameter b are related, then, by the equation:

$$\text{Cos } \theta/2=b/(R+r) \quad . \quad . \quad \text{(ii)}$$

Several shots are made for each value of b, and after each shot the dent in the paper is located and marked carefully. The impact parameter is indicated for each grouping. It is advisable to wear protective shields when performing this experiment, to guard against the effects of a ricochet. Best results are obtained when the hose of the squeeze-bulb used for firing the balls is straight and when the balls are not fired too hard.

The angle θ is determined, so that the second equation above (ii) is verified. Only the angle ϕ can be conveniently measured directly. After all the trials for various values of b have been completed, the paper is spread out on a flat surface, and the arc length AB is measured. Now, since we have $\phi=AB/S$, we get further the equation:

$$\text{Sin } (\phi-\theta)=\left(\frac{R+r}{S}\right) \text{Sin } (\theta+\alpha)$$

$$\text{where Sin } \alpha=b/(R+r) \quad \text{(iii)}$$

This can be rearranged in the form:

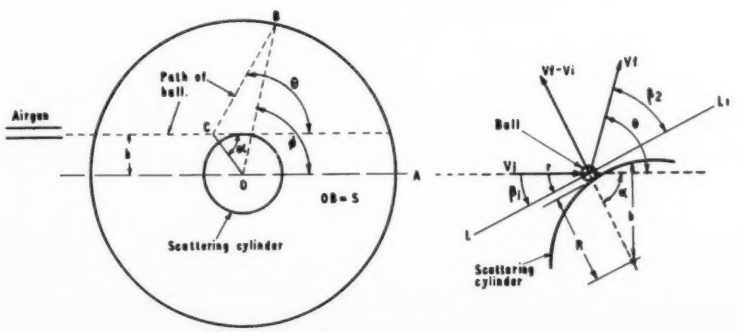
$$\tan\theta=\frac{\text{Sin } \phi-(b/S)}{\text{Cos } \phi+\left(\frac{R+r}{S}\right)\text{Cos } \alpha} \quad \text{(iv)}$$

In order to find the angle ϕ we must know $(R+r)$. Provided $(R+r)/S$ is small, then equations (ii) and (iv) will allow the value of $(R+r)$ to be found from observed data. If $(R+r)/S<1$, angles θ and ϕ are very nearly equal. Suppose, for example, $S=38$ cm, and $(R+r)=3$ cm, and since Sin $(\theta+\alpha)$ cannot exceed unity, then Sin $(\phi-\theta)$ can never exceed 0.08, so that ϕ and θ cannot differ by more than about 5°. Now (Cos $\phi/2$) is plotted against the impact parameter b, and from the slope of the curve a first approximation to $(R+r)$ is found. The equation (iv) gives us now a second approximation to the angle θ. Now, Cos $(\theta/2)$ is plotted against b, and this gives a second approximation for $(R+r)$. This procedure is followed until $(R+r)$ as computed from equation (ii) does not vary significantly from one approximation to the next. It is also possible to get a first approximation to $(R+r)$ by assuming $\theta=\phi$, and then the intermediate stages are bypassed, using a directly measured value of $(R+r)$ to compute the value of each angle θ.

No. 55 Detection of atmospheric radon

Radon, a daughter product from radium, is seldom mentioned as contributing to natural background. It is constantly replenished, and decays with a half-life of about four days to give longlived daughters which emit penetrating beta and gamma radiations. Since radon is an alpha emitter, it is best detected by means of an electroscope or by photographic methods.

An electroscope is charged and its background drift rate determined



Particle scattering experiment

over a sheet of the filter paper which is to be used in the experiment for collecting the radon.

The filter paper is fixed over the intake tube of a vacuum cleaner by being fitted over the tube end and anchored by a strong rubber band or with Scotch tape. Air is drawn through the paper for half an hour. The filter paper is then removed, a pencil mark made around the edge of the area over which the radon has been trapped, and the drift rate again determined.

No. 56 A simple spinthariscope

F. R. Paulsen, U.K.

Enough of a hot 20 per cent. uranyl nitrate, 5 per cent. gelatine solution is made to nearly fill a Petri dish, and allowed to set. A 6 in. square of cheesecloth (or similar) is soaked in gum-arabic solution, then sprinkled with zinc sulphide powder. The cloth, after being stretched over the Petri dish, is allowed to dry. The cloth may be secured by means of paraffin wax. In the dark, by means of a magnifying glass, flashes on the zinc sulphide screen indicate arrival of alpha particles from the uranium.

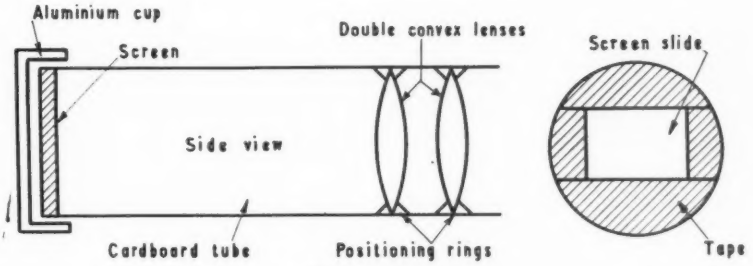
No. 57 The iodine-iodide equilibrium

From the 1952 Summer Conference of the New England Association of Chemistry Teachers in the U.S.A.

Four equal portions of a potassium iodide solution, about 0.01 g each, are placed in separating funnels, and two portions are labelled with 5 microcuries of I131. One spiked and one inactive sample will be oxidized with hydrogen peroxide, the iodine being extracted by carbon tetrachloride. The spiked iodine is drawn off into the inactive iodide, and *vice versa*. After a brief period of shaking, the layers are separated and the gamma activity of the four portions is determined. The equal distribution of activity in these demonstrates the dynamic nature of the iodine-iodide equilibrium.

No. 58 Isotope Uptake by incised leaf-tip

One problem in this experiment arises from the fact that one is dealing with altered or damaged tissues, and that transpiration must be considered. The plants used are two coleus or geranium plants 6-8 in. tall. The solutions are contained in four empty, clean, half-pint paper milk cartons. The last one-fifth of a large leaf tip is cut away and this leaf is immersed with the cut edge a short way into the radioisotope solution. The folded tops of the small milk cartons are cut away to make waterproof containers. To 150 ml of phosphate carrier 5·0 microcurie of P32 is well mixed, and in this nutrient the plant parts are immersed. The roots of the plant should be held in a non-radioactive solution in a similar carton, while the cut leaf is inserted into the radioactive solution. Transport of the radioactive material is compared with that taken up by the root or stem or foliar application. Fluids taken up in this experiment replace those lost in transpiration and the P32 is merely carried along with the water. The transpiration rate should be compared with that determined by other methods, such as that in which the movement of an air bubble is measured.



A simple spinthariscope

No. 59 A simple spinthariscope

Commercial mucilage is diluted with an equal volume of water, and applied to a square of Saran or similar wrapping material, to give a clear thin film. While this film is still moist, powdered zinc sulphide is sprinkled on to it, through a thin piece of gauze, care being taken to ensure even distribution. The film is now dried. Two double convex lenses are fitted inside a cardboard tube (that from a toilet roll will serve the purpose well.) The principal focus should be about $^1/_{16}$ in. from the opposite end of the tube. The zinc sulphide screen is secured to that end of the tube opposite the lenses, the screen side facing the lens system. The screen is held in by Scotch tape. Two "dishes" are made from aluminium foil. One is used to cover the eyepiece lens when the instrument is not in use. The other contains the radioactive material which is held against the back of the zinc sulphide screen. The source of alpha particles is a powdered Welsbach or similar gas-mantle, evenly spread into the sample dish, and retained by some mucilage. The spinthariscope should be taken into the dark, with the alpha particle source applied to the back of the screen. The scintillations are twinklings of greenish light. The radioactive source may also be a minute or hour hand from a discarded bedroom clock, and in this case even the zinc sulphide screen may be omitted.

No. 60 Chromatographic separation of radium-D, E and F

Fausto W. Lima, Brazil.

Strips of No. 1 Whatman paper, 2.5×40-50 cm are used. To a pencil mark in the middle of each strip, 5 cm from one end, the solution of Ra-D, -E, -F is applied, 0.01 ml being used. This solution may be prepared by dissolving a spent radon seed (in its gold capsule) in 0.4 ml of *aqua regia*. The end of the paper is placed in a glass trough about 20 cm in diameter, so that the solution spot appears about 2 cm from the edge of the trough. The trough is placed so that it rests in the enlargement or flange at the end of an 80 cm length of 20 cm diameter stoneware drainpipe. The other end of the pipe rests in a tray containing butanol saturated with 3N HCl. Three or more paper strips can hang down simultaneously. A glass sheet is placed over the top end of the pipe, after the trough has been filled with

the butanol-HCl mixture. After 18-22 hours, the paper strips are removed and dried. The solution used was a saturated solution of lead nitrate tagged with the Ra-D, -E, -F, and acidified with nitric acid to *p*H 2.5. The activity used was about 0.3-0.4 microcurie/ml.

No. 61 Science demonstration sets

Education Supply Association, Ltd., London.

Designed by Dr. Lindstrom of Nordstedt Skolavdeling, Stockholm, Sweden, these very valuable Science Demonstration Sets are much in demand by science teachers in schools and colleges. Each set, with a slight resemblance to a Meccano set, is in a stout wooden box, and constitutes a portable miniature laboratory, the parts being readily assembled for demonstration and student experiments. Costing £28 10*s*., the General Physics set is designed for about 50 experiments on gravity, friction, pendulum problems, pulleys, levers, mass, volume, density, gases and liquids, and pumps. There are similar sets for Heat and for Light, and especially useful for teachers of atomic physics is the set for Magnetism and Electricity. This set costs £28 10*s*., and its possibilities are extended by Electricity Set 2, which includes telephones, loudspeakers, thermionic valves, and equipment suitable for quantitative electrical work.

No. 62 Uptake of nutriment by plants

Ralph T. Overman, David L. Coffey and Lowell A. Muse, U.S.A.

About 80 microcuries of P32, in 100 ml of water, together with 1 g of sodium phosphate, is used as the culture medium for a small tomato plant, the clean roots of which are in the solution. A GM dosimeter is used to survey the leaves of the plant, the count-rate increase being established by counts taken at 15-30 min. intervals. After 2½ hrs, the plant is taken from the solution, the roots are cut off and rejected, and the remainder of the plant is enclosed in a plastic bag and placed within an X-ray exposure holder. An X-ray film is placed below the sample (in the dark-room, of course), and the folder is closed and sealed light-tight. The film is developed after six hours, and shows the distribution of P32 in the plant.

No. 63 A study of diffusion

United States Atomic Energy Commission.

This experiment shows the diffusion of iodide ions into a solution of potassium iodide. Into a 500 ml graduated cylinder 500 ml of 2N KI are poured. At the bottom of this, solution is layered carefully from a long pipette 25 ml of 2N KI containing 10 microcuries of I131. The activity of the solution is recorded at once, the counts per minute (c.p.m.) being determined by means of a GM probe held at the 0, 50, 100, 200, 300, 400 and 500 ml levels, corrections for background being applied. Similar readings are taken after 1, 4 and 15 days. Finally the solution is stirred and the readings again taken.

The readings show that diffusion is noticeable after 24 hrs, and is virtually complete after 4 days. After complete mixing, the top and bottom readings are lower than the others. This is the result of the lower geometric efficiency when the GM probe is held at the extreme ends of the cylinder.

No. 64 Phosphorus up-take by spores of a mould

About 100 ml of potato dextrose-agar culture medium is prepared by macerating a potato and adding 50 g to commercial dextrose-agar which is then made up according to the manufacturer's directions. About 20 ml of this medium is poured, while still hot, into each of five Petri dishes. Before the agar hardens, 2·5 microcurie of P32 solution is added to each of four of the Petri dishes, the fifth being kept as an inactive control. Each of the plates is swirled gently to assist homogenization, and the dishes are then cooled until the medium becomes hardened. Counts are taken of each plate.

The black mould found on old bread, *Rhizopus nigricans*, is used as the test organism. By blowing across the mouldy bread one can direct spores from the black sporangia on to the Petri dishes, which are then kept at room temperature for culture.

A count is taken on each of the radioactive dishes at regular intervals, the count rate in s.p.m. being recorded for each plate and plotted against time. When mature sporangia are produced, some of these are removed by touching them with a short length of Scotch tape, the sticky side of which adheres to the spores. The total number of the spores is counted under the microscope. The radioactivity of this material is determined by placing the spores very close to the GM tube and the time taken for a count of 6,000 is estimated. The c.p.m. per sporangium is thus estimated. Data from the four dishes are analysed statistically, or an average activity is calculated. Should a reasonably high count be recorded, some of the sporangia should be seeded on to new culture medium in Petri dishes. After reculture, the new mucelia, hyphae and environment may be examined for radioactivity.

No. 65 Radiometric analysis for potassium

Potassium is frequently included in mixtures given as qualitative " spots " to chemistry students. It is an instructive exercise to prove the presence of the potassium radiometrically. The specific beta activity for KCl is 0·919 d.m.p./mg. GM counter efficiency for the K40 beta particles is about 25 per cent. Thus, 25 mg of KCl mixed with other ingredients should give about 10 c.p.m. above background. This activity is statistically significant and easily detected by counting over a period of five minutes.

The sample, if a solution, is evaporated to dryness on a small watchglass or planchette. The weight need not be determined. The c.p.m. is determined close to the GM tube, and corrected for background. The presence of detectable radioactivity in the sample may be taken as presumptive evidence of potassium in the unknown, provided there is no contamination with elements of high atomic weight as natural emitters, or elements rendered radioactive through nuclear reactions.

As an extension of this experiment the student might determine the fraction of normal potassium which is actually K40. The $\frac{1}{2}t$ value for this nuclide is $1{\cdot}2 \times 10^9$ years.

No. 66 Radiation and the chromosomes of Tradescantia

Immature flowers of Tradescantia are used in this experiment, the form *T paludosa* being quite suitable. In one series the flowers are irradiated with a 250kV X-ray machine at an exposure level of 420r, fixed in a mixture of acetic acid and alcohol, and stored in 70 per cent. alcohol. In the other series, the flowers are controls which are similarly treated except that they have not been irradiated. In Tradescantia, chromosome morphology can best be studied during the nuclear division in the microspore giving rise to the generative and tube nuclei of the mature pollen grain. Smears of microspores from both series of flowers stained with aceto-carmine, will be used. The preparation is according to the following schedule:

A bud about 4 mm long is placed on a slide, the petals and sepals being carefully dissected off. The stamens are isolated, and the anthers are separated from the filaments, the latter being rejected. The anthers are placed in a small drop of aceto-carmine stain and crushed with a needle, the anther tissue being removed to leave the microspores in the centre of the slide. Avoiding air bubbles, place a cover-slip on, and place the slide for 45 sec on the mouth of a one litre Erlenmeyer flask in which water is boiling. The slide is now removed and blotted between Kleenex tissue, with gentle pressure. To the edge of the cover-slip is added a drop of 45 per cent. acetic acid, and the flask is again used for heating the slide for 10-15 sec. Again Kleenex is used for blotting. The slide is then examined under the microscope, using low power, then high power. This is repeated until good differentiation has resulted. The chromosomes should be seen as stained, separated and transparent, but clearly defined. The cytoplasm should be virtually unstained. The slide is now sealed with a mixture of paraffin and bees-wax applied to the edge of the cover slip to prevent evaporation. When satisfactory smears have been made a comparative study of mitosis in both irradiated and control material is made. All stages of mitosis can usually be found. In the irradiated material it should be possible to find the following: (*i*) terminal chromosome deletions, as rounded, short structures adjacent to other chromosome structures; (*ii*) intercalary deletions, many pieces having their ends joined to form ring-shaped structures; (*iii*) chromosomes with two or more attached regions or centromeres. Each chromosome normally has only one such region, appearing as a non-staining constriction which in this plant is typically equidistant from the ends of the chromosome. Comparative drawings of the cells in metaphase from both irradiated and control material should be made, large enough to be informative.

No. 67 Calculating no-screen X-ray film exposure time

For successful radioautography it is essential to know the correct exposure required for a given amount of radioactivity deposited in or on a given biological material. The time is a function of the c.p.m. and the area of the end-window of the GM tube being used.

Suppose the end-window of the tube has a radius of 1·5 cm. Then the receptive area is $3{\cdot}14 \times (1{\cdot}5)^2$. $= 7{\cdot}07$ cm^2. Suppose the biological material, after being dried and pressed, gives a count-rate of X c.p.m./cm^2. If the material is as large as the end-window, then the registered c.p.m. will be $X/7{\cdot}07$. Suppose, for example that X is 7,070 c.p.m., then the count rate is $7{,}070/7{\cdot}07 = 1{,}000$ c.p.m./cm^2.

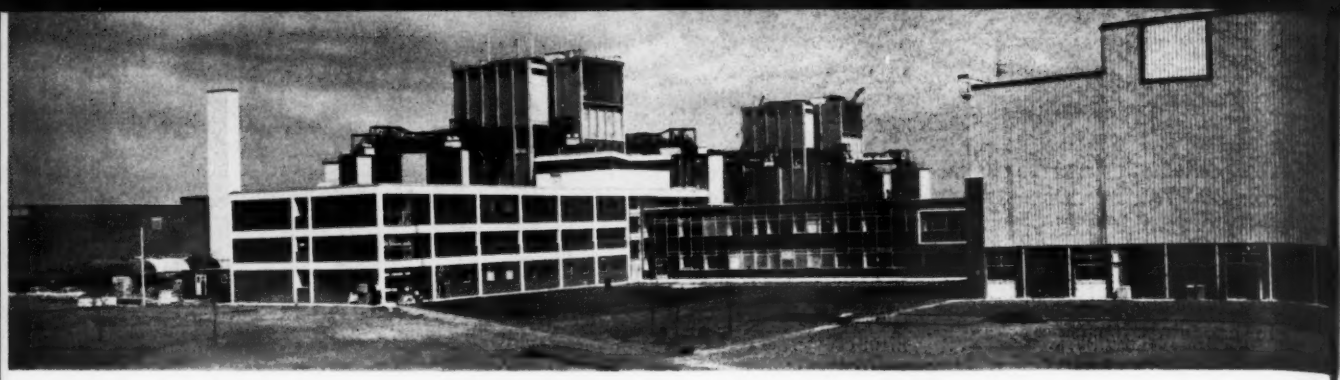
The suitable exposure for a No-screen X-ray film may be taken as 10^6 to 10^8 photons, so that the exposure time will be given by 10^6/c.p.m./cm^2 or in the given example, $10^6/10^3 = 10^3$ min, or about $16\frac{1}{2}$ hours. The activity range in biological material will probably vary widely from area to area, and it may be difficult to choose a portion as a guide to selecting a suitable intermediate level of activity. This problem does not arise when the material has a surface area smaller than that of the GM window. The biological material chosen should show the greatest movement of radioactive isotope to give a dense image. If desired, the material may be sandwiched between two X-ray films. At the end of the calculated exposure period, the top film is removed, developed and evaluated in terms of how much longer the bottom film has to be exposed in order to give a good exposure. The same exposure and development schedules are to be followed for all materials in a given experiment, or course.

No. 68 Electroplating

United States Atomic Energy Commission.

It is the object of this experiment to show that the atoms which are electrodeposited during electrolysis of a solution come first from the solution, and then from the anode, to be deposited on the cathode.

A bath of inactive cobalt nitrate is made by dissolving 40 g of the salt in 75 mls of water and 25 mls of concentrated ammonia solution. A radioactive anode is now prepared as follows. The plating bath is made as above, but with the addition of 1 ml of Co60 solution (from National Bureau of Standards), and a copper square is used as the cathode, the anode being a graphite rod placed 2 in. from the cathode. With a current of 0·05 amp, electrolysis is continued for 30 min, so that the copper cathode gives a reading of about 1,200 c.p.m. with a GM counter. This copper is now used as anode in the cobalt nitrate (inactive) prepared as above, the metal sheet being about 1 in. square and it is placed in the bath, another copper plate of the same size (but inactive) being used as the cathode. The plates must be about 4 in. apart. Electrolysis is carried out at 0·05 amp using a 6v dry cell. The radioactivity of the cathode and the bath is determined at 15 sec intervals. A typical experiment showed that there was a slight black deposit after 30 sec on the cathode, but no radioactivity was detected on the cathode until 2 min had elapsed. Even then, this was only slight. During the same period the activity of the solution increased. The activity on the cathode was proportional to the ratio of the active to inactive cobalt in solution. This means that cobalt atoms which are first plated out on the cathode, come from the solution, and that these are replaced by cobalt ions from the anode. △△△



Berkeley Nuclear Laboratories

WITH the recent opening of Berkeley Nuclear Laboratories the CEGB will now be making a large direct contribution to research for the Nuclear Power Station Programme in this country. In all the CEGB has already spent about £2m. in building the laboratories which provide a total floor area of 100,000 sq.ft. Considerable provision has been made to meet requirements for future expansion with the minimum of inconvenience and expense. The laboratories come under the control of the Research and Development Department of the Board which was established with the setting up of a comprehensive nuclear power laboratory as one of its objectives.

Berkeley was chosen as the site for the laboratories for a number of reasons, it is next to one of the first civil nuclear power stations, two major cities are within easy reach, the area is suitable for future nuclear development and last but by no means least in this age of emigrating scientists, high grade technical and scientific staff can be attracted to the region comparatively easily.

Despite the huge amount of effort which has already been put into research on civil nuclear power stations in this country the fact still remains that the answers to many important questions are still required. Clearly, now that the civil power nuclear programme is on the verge of producing results, the answers to these questions will soon be of vital importance to the CEGB. It is, therefore logical that the Board should be provided with the means of solving their own particular problems. To make the nuclear power stations which are at present being built work economically and to develop improvements for the next generation much intensive work is planned by the Board on the nuclear reactor, materials, physics and engineering.

To deal with the various aspects of its work the laboratory has been divided into three divisions, Materials Division, Physics Division and Engineering Division. The Materials Division has some of the most advanced equipment in the world for examination of radiation damage to materials from a reactor. Interest is concentrated on two problems, damage to permanent constructional materials, especially steel and graphite and the behaviour of fuel elements. It is essential that the constructional materials shall give maximum service life and that the fuel elements should last as long as the effective life of the uranium they contain.

Physics Division

Physical aspects of nuclear power generation are the responsibility of the Physics Division. Much further work is required on core reactor physics; this will be carried out at Berkeley on exponential assemblies of graphite and fuel elements. Physics Division will also carry out a very extensive programme of measurements on graphite samples from all the Board's reactors. The object of the Board is to establish the integrity of reactor cores and to ensure that the maximum life consistent with complete safety is obtained from each reactor. Other work to be done concerns problems arising in nuclear instrumentation, high energy gamma ray dosimetry and intermediate energy neutron measurements.

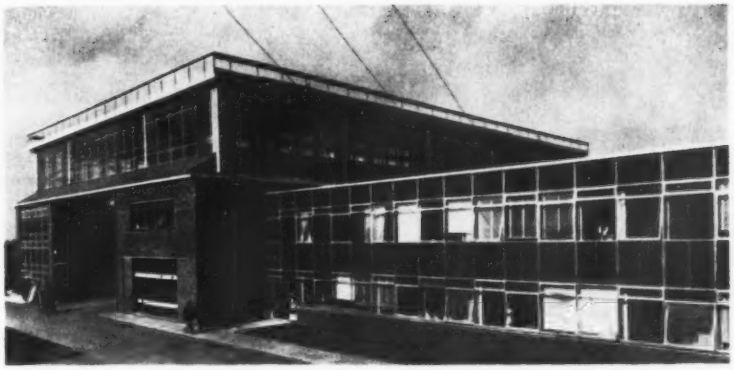
Engineering problems will be examined in the Engineering Division which has been equipped with rigs for studying heat transfer properties and mechanical endurance of fuel elements under full reactor conditions of temperature and pressure. Mechanical tests are to be carried out on pressure circuit components and the complex stress systems involved will be studied.

Safety

Safety is one of the keynotes of the laboratories, stringent precautions are in force at Berkeley itself and much of the work carried out will be designed to increase or at least ensure the maintenance of safety standards at all of the Board's nuclear power stations. A Health Physics group has been set up at the laboratories to safeguard personnel.

Much of the work to be done at Berkeley, especially by the Materials Division involves the handling of highly radioactive materials. Because of this a shielded area has been constructed at the laboratories, mainly for the use of the Materials Division. Entry to the shielded area and the laboratory wing is through change rooms, all personnel put on protective clothing which is later washed in the adjacent laundry. An air conditioning system supplies warm fresh air to the buildings and later

extracts it through extremely effective filters which remove all radioactivity before discharge through a 75ft high chimney. In this system a slight negative pressure is maintained inside the buildings. All drains from radioactive areas lead to hold-up tanks where effluent is effectively freed from any traces of radioactivity before discharge.



View of laboratories showing the Engineering Hall on the left

Shielded Area

The shielded area is about 180 ft long by 100 ft wide, it has been designed to enable easy handling of fuel elements and reactor test specimens. On removal from a reactor, fuel elements are encased in outer cans, up to 30 of which are enclosed in a large shielded flask for transport. At the laboratories these flasks will be unloaded straight into the pond in the shielded area.

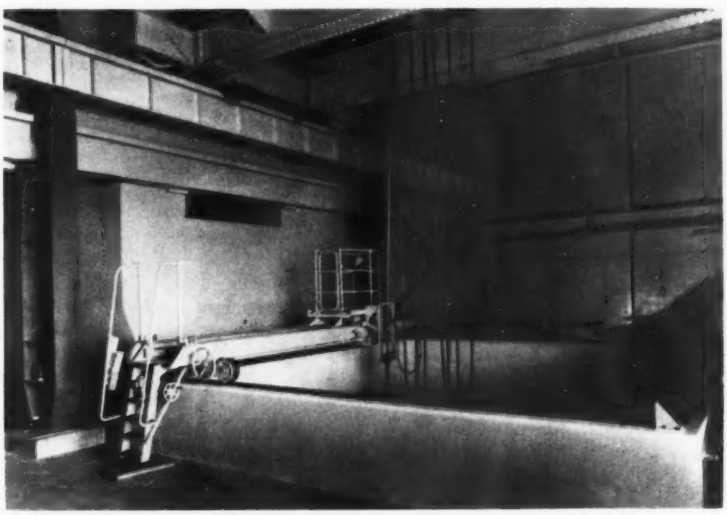
Each flask contains up to 1m. curies of radioactive material which in the course of examination will be reduced to specimens with an activity as small as one curie. The flasks are opened in the pond, as required, under about 20 ft of water, an element is withdrawn and transported on a conveyor through a shielded tunnel into the first of a set of three caves.

Observation of the caves is provided through lead glass windows filled with zinc bromide solution, and shielding is by $\frac{1}{2}$ in. thick steel and 5 ft thick concrete walls. Each cave measures 9 ft square by 14 ft high, is separated from its neighbour by a $2\frac{1}{4}$ in. thick power driven sliding panel and any one cave can contain an activity of 50,000 curies with 10,000 curies in each of the other two caves. Concrete sliding doors give access to the maintenance area at the rear.

Operations within the caves are carried out by remote control, manually operated, remotely controlled manipulators are provided for each cave. The power-driven manipulator which runs on overhead rails through all the caves can be connected to the emergency electrical system in the event of a power failure.

In the first cave the fuel element is inspected visually after being removed from its container. In the second cave it is inspected with metrologic and radiographic equipment. The last cave is equipped with leak detection equipment. Having undergone this first preliminary examination the element is returned to the first cave where two cutting machines remove the alloy can. The uranium bar is then sectioned and moved to the third cave for the separation of specimens for mechanical tests and metallographic examinations.

A shielded railway then takes the specimens to a set of nine cells at right angles to the caves. In these cells the shielding is such that when one cell contains 500 curies of activity each of the others can contain 100 curies. The shielding materials consist of concrete, steel and lead.



The pond in the shielded area into which large flasks containing up to 30 fuel elements are unloaded

Cell Utilization

Two of these cells are used for machining operations on test specimens, a third houses an Instron tensile testing machine and another is used for metrology. Other cells are devoted to steel specimen monitoring, an encapsulating rig for sealing specimens in silica and several furnaces for subsequent heat-treatments. Two more cells are used for general work and for carrying out short term experiments and the last one for storage and general decontamination work.

A number of lead boxes have been provided near the cells for work on specimens of less than one curie activity. They are used mainly for metallographic examination and testing and for small-scale physical chemistry. The lead boxes are contained in cubicles with access from the cell operating area, they are designed for operation from two sides. The ventilation systems for the caves and cells on the one hand and the operating areas on the other

are separate. Before discharge the air passes through several filters; a fire-proof filter inside the cave, a flame-proof absolute filter immediately outside and a second flame-proof absolute filter in the plant room. Similar precautions are taken with the gaseous effluent from the cells, lead boxes and operating areas.

Liquid effluent from the caves, workshop and decontamination centre is treated with flocculation precipitation before being mixed with low activity effluent from other areas.

The laboratory wing is a three-storey building, intended mainly for the use of the Materials Division but which also includes the solid state physics and graphite sections of the Physics Division. Investigations will be carried out in this wing into the behaviour of reactor materials.

The engineering hall is situated on the south side, is 160 ft long by 115 ft wide. The hall contains a number of laboratories as well as the main workshops and rigs. The hall contains most of the facilities for the Physics Division and also those for the Engineering Division.

The hall has been designed to manufacture all the rigs and equipment required in the laboratory. Two exponential assemblies are to be erected on the floor of the hall to investigate absorber design and the effect of vacancies in reactor lattices. The heat transfer properties of fuel elements will be investigated in two specially constructed rigs. Fuel element cans fitted with electric heaters are placed inside these, and cooled with atmospheric air. A closed circuit pressurized rig, cooled with carbon dioxide, is shortly to be added for heat transfer studies under reactor conditions. A rig has been built for endurance tests on fuel elements which contains a dummy channel in which complete fuel elements can be tested.

Visual rig

A visual flow rig has been constructed in which water, loaded with fluorescent dye is pumped past a fuel element held in a Perspex tube to demonstrate fluid flow patterns around the element. Three rigs have been designed for measurement of the force required to push off an end cap under a variety of representative temperature and pressure conditions.

Thermal cycling effects in fuel elements are to be studied in a group of four rigs, three of which provide slow rates and one fast rate of thermal cycling. Rigs have also been built for investigating mechanical effects of fin vibration and fuel swelling. Seal test rigs have been installed to investigate the behaviour of O-rings.

Berkeley Laboratories have cost the CEGB a large amount of money but there can be little doubt that in return the Board will achieve considerable savings in the future as a direct result of work to be carried out at Berkeley. In addition to this, the safety factors at civil nuclear power stations will become progressively larger and more reliable as the results of research at Berkeley find practical application. △△△

Discussion on
"Nuclear Reactors in Universities"

by N. S. Grassam

Dr. Paulsen: I was rather interested to hear your remarks about the curtailment of support for further teaching reactors in the United States, and I wondered to what extent the firms who manufacture these reactors are aware of that. Secondly, I wonder what you consider to be a rational number of teaching reactors in the U.K?

Dr. Grassam: To answer the second question first, I would say certainly not more than six. Regarding the first part of the question, I should imagine that the firms concerned read the literature and I cannot see how they could fail to appreciate this point.

Dr. Paulsen: I take it, therefore, that the major source of their market is overseas.

Dr. Grassam: They would hope so.

Capt. Atkins: Where would Dr. Grassam like the reactors precisely?

Dr. Grassam: I would like one. —I think a reasonable distribution throughout the country could be achieved on a north, south, east and west regional basis.

Mr. Shaw: One in Scotland, one in England, one in Wales, one in Northern Ireland and one in Southern Ireland (laughter). Can you say where teaching reactors are being planned for the future?

Dr. Grassam: The places which I know are planning to have reactors are Queen Mary College, London, the Imperial College, London, Manchester and Liverpool Universities with a combined one, Glasgow and Southampton Universities. Those are the places which I know have definite plans. On tentative planning I know that a number of these have applied for licences to have a reactor on a particular site, but no financial provision has yet been made to have any reactors at all. All that has happened is that applications have been made for sites to be licensed. It does not mean that you have permission to have a reactor. We are awaiting a Government decision on this, and you may, if you read Parliamentary debates, have noted the Minister of Power stalling in his replies to questions on this matter on several occasions recently.

Mr. Wyatt: I wonder if you can tell me if there have been any approaches from the universities to industry in this country, bearing in mind particularly facilities in the States. Industry in this country has relatively few critical facilities of their own, or any facilities at all for that matter. I think this is ridiculous as many big firms have their own facilities in the States. Have any approaches been made to fill any requirements which industry in this country might have?

Dr. Grassam: The only two companies in this country which have

The paper by Dr. Grassam was published in our January, 1961 issue, page 19.

built reactors for themselves in this country are AEI of Aldermaston and the Hawker Siddeley Nuclear Power Company, who built the JASON reactor at Slough. As far as universities are concerned, one of my points is that universities are unlikely to make use of facilities at a distance. I would hope that when universities have reactors they will be able to offer time on them for industry. Hospitals, of course, are an obvious user. It is difficult to think of many industries requiring much time on a reactor. In fact, I think if any industry really wanted time on a reactor it would get it now.

Mr. Williams: I do think we ought to draw attention to the facilities which exist at Imperial College, which have been in existence for some time. Of course, it is not a major job in the critical sense, but it has given a lot of information. On the point which has been raised about the utilization of facilities, which is, of course, an attempt to recoup some of the capital which has been invested, I do suggest that reasonable university facilities could be used in hospital work in the field of isotopes and for industry. In your reference, Dr. Grassam, you rather suggested that a reactor was merely a teaching aid. Of course, British universities with their long tradition of research have this two-fold aspect of teaching and research and I think more emphasis could have been made on this use of university reactors as a means of research, and stemming from this is the fact that although a lot of people want to do research on reactors I do not think it is true that reactor facilities are easily obtainable. It is my experience that the reactor facilities at the Atomic Energy Authority and the two industrial reactors are fully occupied and it is extremely difficult to get any useful space when anyone wants to. So, I think university reactors will play a very useful part in providing these facilities.

Dr. Grassam: I did think that I had emphasized in my lecture that research was the main reason for having university reactors, rather than teaching purposes. But I do see your point, if I did not make that clear. As regards the facility of Imperial College, I do agree it has been there for a long time and has done some very valuable work. There is also a sub-critical assembly at Queen Mary College and I believe that Birmingham has one as well.

Dr. Salmon: I am a great believer in reactors in universities, and my impression of this was strengthened some weeks ago when I was at a conference on pile neutron research. Attending this were representatives of universities abroad and the Atomic Energy Authorities and Atomic Energy Commissions of various countries. To my mind the most impressive paper of all reporting work about a reactor was from the University of Munich, where they have a 1 MW reactor. They have about 30 experiments going, all of a standard which could be reported at an international conference, so I think this emphasizes that universities can use reactors, but there is one very important thing to be borne in mind and that is that one must not under-emphasize the cost of this sort of work. The total investment in the Munich reactor is over £1m., and it does require a very big and competent staff to run a reactor of this type from the safety point of view and also to supervise it from the research point of view, so I do not think we ought to under-emphasize these reactor requirements. As regards the stages of development of the powers of the reactors, I think we are right in thinking now about the 10 to 100 kW range of reactor, because I am sure that it will eventually lead to something. Possibly one or two national reactors for university use—perhaps with the relevant authority—in the 5MW range. In 1954, AEI made a survey of universities in the U.K. having strong nuclear physics teams, because nuclear engineering, especially at universities, was virtually non-existent. The impression then was that a reactor of the 5 MW range was what was wanted by people who know what they want to do. Unfortunately, the money has not been available and there were siting difficulties, but I am sure this is still the future and I am sure it is going to come. I think in reply to Dr. Grassam and Mr. Williams, there are facilities available at Aldermaston on MERLIN, which we have said we will give free to the universities for research work and we will help training operations as far as we can. But on a post-graduate level I would say that perhaps the initial training around a 100 kW reactor would still be useful for when they want to progress to higher fluxes for slightly more sophisticated problems. There was just one point with which I disagreed in your paper, Dr. Grassam, and that was this use of the words " inherently safe." We have thought about this for six or seven years now and my conclusion is that I do not believe there is an inherently safe reactor. Just looking at it from the point of view of radioactivity, mechanical handling and so on, if you have a 100 kW reactor you can have 100 kilocuries on your site and I do not believe 100 kilocuries of radioactivity is ever inherently safe. We do not use this word any more.

Capt. Atkins: For the record, Dr. Grassam, there is one reactor which I certainly hope will be coming along. I hope I am not speaking out of turn, but that is the one at the Royal Naval College at Greenwich.

Dr. Grassam: Yes, I had forgotten that one.

Mr. Coombes: I gather from your remarks that the Government is rather reluctant to come forward with funds for these reactors and I wondered whether the universities have thought of approaching the big charity organizations or foundations, such as the Nuffield Foundation.

Dr. Grassam: We would certainly like endowments, I must say, but the money involved is rather large, say £¼m., plus the running costs. The universities would have to be quite certain that the support would be continued and not just a short term gift. We like endowments, but I think we must rely on the Government for such ambitious schemes as this.

(Replying to Prof. Edwards of the Royal Naval College, Dr. Grassam apologised for not mentioning the reactor there. He was aware of it, of course. On another point raised by Prof. Edwards, Dr. Grassam agreed that accelerators could do very useful work, but he felt they were a physicist's tool rather than an engineer's. He did not feel they gave the same value in engineering training as a reactor would.)

Mr. Shaw: I would like to say how much I appreciate this talk. I think it has greatly filled a need because people do not often talk about research reactors in terms which

ordinary people can understand. This brings me to my question which is connected with the previous gentleman who raised the $64,000 question. I think this $64,000 question is one which has just got to be answered, if an amount of money is going to be put up by the Government. (I am speaking as a tax-payer.) Because, you see, in power production the problem is comparatively simple. We have got an end product which we can measure, or at least demonstrate on paper, and that is the cost of electricity. Then we have the question—what is the possible criterion for a research reactor? Surely, it is the research programme or teaching programme which it will carry and in my limited experience of the requirements of various potential customers for research reactors it is that rarely, if ever, does one hear the same story. Now unless one goes to the potential authority and tries to put oneself in the position of a central Government trying to allocate funds it cannot be a very good case to put forward a fragmentation of ideas. So, surely, if this thing has got to be done, all universities should get together and hammer out a programme which all reactors must be capable of doing whatever else the researchers will also do on their individual reactors.

Dr. Grassam: I agree with Mr. Shaw. I do think that at the moment each university is sticking up for its own ends. On the question of the programme, it is a little difficult to predict what you are likely to want to do in two years time when science is moving as rapidly as it is at the moment. I can tell you some programmes of work which want doing at the moment, but whether they will still need doing in two years time is another matter. △△△

Book Reviews

Plasma Physics. Edited by James E. Drummond. Published by McGraw-Hill Book Co. 386 pp.

Apart from the "local pub," where would one expect to find the meeting-place of the nuclear physicist, the astronomer, the aircraft engineer, the electronics expert, and the space aeronaut? Surely, plasma physics would be a suitable common ground, as seems to be indicated by this book. Its 14 chapters present aspects of plasma physics and the problems of research, including those of quantum mechanics, and the basic concepts of classical statistical mechanics. One of the major problems is the interaction of individual electrons with the whole body of electrons in the ionized gas. This has an important bearing on problems in thermonuclear devices, in which runaway electrons interact with plasma to produce high frequency instabilities in the form of amplifications or oscillations. The second major problem is the interaction of plasma oscillations with the electromagnetic radiation field. The problem of the origin and propagation of beams or turbulences falls within the field of magnetohydrodynamics, a science which was born as a twin of plasma physics, and which is of importance to astrophysicists as well as to nuclear physicists. Y. Klimontovich and V. P. Silin contribute a chapter on the spectra of systems of interacting particles. E. Meeron writes on the statistical mechanics of reversible processes in plasma dynamics, largely centred around the importance of the Debye length. The statistical mechanical theory of reversible phenomena finds applications which involve approximations not yet fully understood, but likely to lead to further developments and possible different approaches.

In Chapter 4, on amplifying and evanescent waves, P. A. Sturrock clarifies terms used in electrodynamical analyses, and O. Bunemann distinguishes between attenuating and amplifying waves, an analysis of travelling wave tubes or amplifiers involving a "dispersion equation" connecting frequency with the propagation constant. Y. A. Yoler reviews hydrodynamics, dealing with the interaction between magnetic fields and electrically-conducting fluids in motion. O. Bunemann shows how the Bennett pinch is an ideal model conforming to certain conditions, the practical application of which still is a long way off, the pinch stability remaining uncertain for the present.

In "Stability of Relativistic Self-Focusing Streams," D. Finkelstein and P. A. Sturrock discuss the properties of streams of ions and electrons moving in opposite directions with relative velocities near to the speed of light. Such structures were recognized as possible at high energies and currents by Bennett (self-focusing) and Tonks (pinch effect). The results of analysis of such plasmas are not altogether discouraging, but a more powerful mathematical analysis is called for. Pure magnetohydrodynamics cannot be applied to present-day relativistic stream problems, unless currents over 17,000γ amps (much greater than any so far contemplated) can be made possible. P. A. Goldberg, in discussing properties of high altitude ionized shock waves, points out that above Mach 10, air in a shock wave is very different from air at rest, and at Mach 13-25 intense heating and ionization result in formation of over 20 products of decomposition. Studies are urgently required on the electrical properties of air in hypersonic shock waves. O. Bunemann reports progress in the theory of transverse plasma waves and plasma vortices, this being very slow and difficult. Microwave diagnostics for controlled fusion form the subject of C. B. Wharton's chapter, in which certain probe circuits are described. J. E. Drummond deals with plasma magnetic theory, and shows how the results of experiments are used to derive the radial dependence of radio-frequency charges, current, and electric and magnetic fields. The final chapter, by S. C. Brown, is a fascinating account of plasma physics research at MIT. He points out that slow progress is the result of the need for ensuring that no region which is ill-understood shall be skipped over. This book is a splendid summary of theory and current developments in a very important field, and cannot fail to be of great interest to a very wide readership. It must remain an epic of achievement and opportunity in this fascinating branch of physics. F.R.P. △△△

Monographs received

Analytical Methods for the Determination of Caesium-137, Strontium-89 and -90 in Rain, Lake and Sea Water, presented by technical manager (chemistry), Operations Branch, Windscale. Published by Production Group, Risley. Reference PG Report 155(W). Price 3*s*.

Calculations of the Maximum Permissible Concentrations in Air and Water of Certain Fission Product Mixtures, by S. A. Beach. Published by UKAEA, Harwell. Reference AHSB(RP) R7. Available from HM Stationery Office. Price 2*s*. 6*d*.

Langmuir Probe Techniques in Intense Discharges, by H. W. Jones and P. A. H. Saunders. Published by CTR Division, AERE, Harwell. Reference AERE-R3611. Available from HM Stationery Office. Price 5*s*.

The Relative Inhalation Hazards from the Radioisotopes of Iodine Following Accidental Release of Fission Products, by G. W. Dolphin and S. A. Beach. Published by UKAEA, Harwell. Reference AHSB(RP) R5. Available from HM Stationery Office. Price 3*s*.

Thermal Conductivity Determinations on Uranium Dioxide by Radial Flow Method, by V. C. Howard and T. F. Gulvin. Published by Industrial Group, UKAEA, Risley. Reference IG Report 51 (RD/C). Available from HM Stationery Office. Price 3*s*. △△△

Nuclear Training and Research Equipment

by Otto F. Joklik

Reactor simulation is a highly appreciated and useful method not only for training in nuclear reactor technique, but also for demonstrating clearly and comprehensively various nuclear and nuclear-physical processes. It is therefore important, not only in nuclear technology and engineering in general, but also in nuclear research work.

A Vickers Mk. 1A Reactor Simulator is described in this article and meets all requirements. It embodies all the features expected from such a universal unit.

Any thermal or fast fission reactor, running at low power, can be simulated continuously up to a level of 100 kW. Various configurations of fuel and moderator with the associated range of neutron lifetimes may be represented.

The six groups of delayed neutrons associated with the fuels uranium-235, 233 or plutonium-239 can be reproduced. An additional "simplified" fuel, uranium-235/2, illustrates a two group treatment of delayed neutron effects and emphasizes the effect of delayed neutrons on reactor control.

Provision for the study of the effectiveness of automatic control systems and the calculation of changes in reactivity due to fission product poisoning, temperature coefficient and thermal transient effects can be incorporated to suit any requirement.

The instrumentation provides all the important indications given on the control desk of a full size nuclear reactor. These include a pen recorder giving power indications on one logarithmic and four linear ranges: a doubling time meter and a logarithmic power meter. Shut-off rod and control rod positions are indicated and warning lights show conditions and rod limit positions. A recessed panel is provided to pre-set the initial conditions of the various fuels to be employed.

The range of equipment can be used to supplement lectures on reactor kinetics and courses can be designed around this versatile facility. A fully comprehensive training programme for potential reactor operators can be conducted with a simulator and a core model. Due to its great flexibility, the simulator can be used to represent experiments and power changes of many kinds.

Part 1—Reactor Simulators

The Vickers Mk. 1A Reactor Simulator has been designed and developed to meet the requirements of universities, technical colleges, and nuclear training and research establishments. The simulator can be used to supplement lectures on reactor kinetics, to train potential operators, or to stage reactor experimental programmes. Provision is made for the study of the effectiveness of automatic control systems.

The principle of simulation is that of the analogue computer, in which the simulator system follows the same laws as the reactor being simulated, and continuously solves the equations relating to neutron flux, reactivity, and time, in a nuclear reactor.

Potentially dangerous reactor power excursions can be simulated with complete safety; however, the operator is expected to exercise the same care and precautions in the use of the simulator that he would take in the control of a nuclear reactor.

The simulator is so designed that it can be operated manually or automatically.

The three-panel control console is supported on a knee-hole type desk. The pedestals accommodate the power units and the computer amplifiers. The simulator resembles the control desk of a nuclear reactor with all the essential safety devices and instrumentation.

Any thermal or fast fission reactor may be simulated throughout its power range, up to a level of 100 kW. Simulators for power reactors usually have additional computing circuits for simulating changes in reactivity due to temperature coefficients, fission product poison effects, thermal capacities of the materials of the core, fuel depletion, etc. Such instruments are necessarily either very large, or are confined to the simulation of a single type of reactor.

The six groups of delayed neutrons associated with the fuels U233, U235 and Pu239 are reproduced. An additional hypothetical fuel, U235/2, enables delayed neutron effects to be demonstrated more clearly by providing just one group of them in addition to the prompt neutrons. The mean-life chosen for the delayed group is 13·28 sec, which is the appropriately weighted mean of the six groups occurring with U235.

Thermal and fast reactors may be simulated using any moderator with the exception that the photo-neutrons from beryllium and heavy water are not reproduced. The simulation of fast reactors under normal control

conditions can be achieved and this subject will be discussed further.

Safety simulation is obtained by the incorporation of interlocks and trips to provide actual reactor trip and safety responses.

As its name implies, the automatic start-up system operates the reactor in such a way that the absorber rods are automatically withdrawn and are positioned such that the reactor power builds up to a pre-set maximum in the shortest possible time.

The following notation will be used throughout the equations:

k_∞ = infinite multiplication factor
k_e = effective multiplication factor
k_{ex} = excess reactivity
L_e = leakage rate of neutrons
n = neutron density at any time
v = neutron velocity
Σ_a = macroscopic cross-section for absorption
Σ_f = macroscopic cross-section for fission
l_a = absorption mean free path
τ_0 = mean neutron lifetime—thermalization to absorption
ρ = reactivity
S = neutron source strength
c = fraction of neutrons delayed
$l-c$ = fraction of neutrons prompt
r_j = density of nuclei capable of giving a delayed neutron of type j
μ_j = fraction of delayed neutrons of type j
τ_j = mean lifetime of type j nuclei
λ_j = decay constant of type j nuclei
T_n = reactor period

Consider the case of prompt neutrons alone. The general equation is:

Rate of increase of neutron density
= Prompt rate of production
+ Delayed rate of production
− Rate of leakage of neutrons
− Rate of absorption of neutrons

So that for prompt neutrons alone, and an infinite system, we have:

$$\frac{dn}{dt} = nv\Sigma_a [k_\infty - 1 - L_e]$$

$$= nv\Sigma_a [k_\infty - (1 + L_e)] \quad . \quad . \quad . \quad (1)$$

Now we know that $k_\infty = k_e (1 + L_e)$. . . . (2)

and $$\rho = \frac{k_e - 1}{k_e} = \frac{k_{ex}}{k_e} \quad . \quad . \quad . \quad (3)$$

so that (1) becomes:

$$\frac{dn}{dt} = nv\,\Sigma_a \left[k_\infty \left(1 - \frac{1}{k_e}\right)\right]$$

$$i.e., \quad \frac{dn}{dt} = nv\,\Sigma_a\, k_\infty \rho = \frac{n\rho k_\infty}{\tau_0} \quad . \quad . \quad . \quad (4)$$

since $v\Sigma_a = \frac{v}{l_a} = \frac{1}{\tau_0}$

whence $\log n = \frac{\rho k_\infty}{\tau_0} t + A$

and assuming that $n = n_0$ when $t = 0$:

$$n = n_0 \exp. \left[\frac{\rho k_\infty}{\rho_0} t\right] \quad . \quad . \quad . \quad (5)$$

For a finite system (5) becomes:

$$n = n_0 \exp. \frac{k_e \rho}{\tau_0} t$$

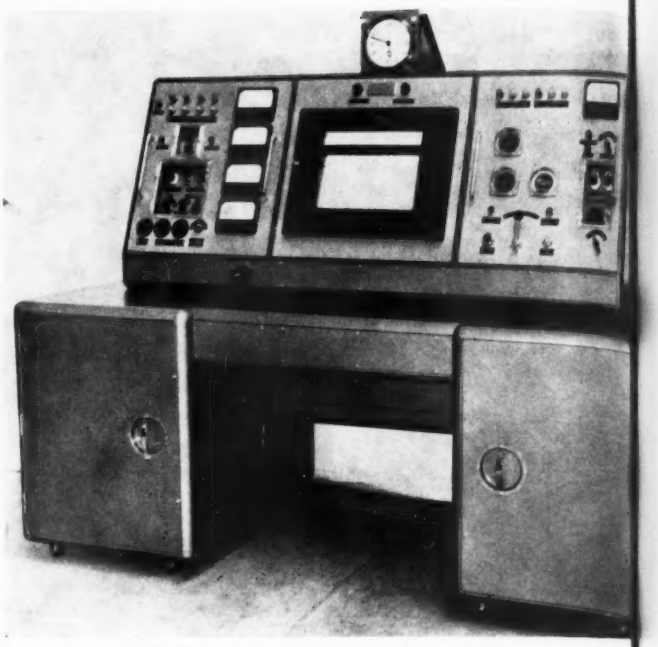


Fig. 1. Vickers Mark 1A Reactor Simulator

$$i.e., \quad n = n_0 \exp. \frac{k_{ex}}{\tau_0} t \quad . \quad . \quad . \quad . \quad (6)$$

If now a source of strength S be introduced, (4) becomes:

$$\frac{dn}{dt} = \frac{k_\infty \rho}{\tau_0} n + S \text{ for an infinite system} \quad . \quad . \quad (7)$$

which may be written in the form:

$$\frac{dn}{dt} + An = S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where $A = -\frac{k_\infty \rho}{\tau_0}$

which gives n exp. At $\frac{S}{A}$ exp. At + constant, and if $n = n_0$ at $t = 0$, then:

this gives $n = \frac{S}{A} + \left(n_0 - \frac{S}{A}\right)$ exp. At

$$i.e., \quad n = \left[\frac{S\tau_0}{k_\infty \rho} + n_0\right] \text{exp.} \frac{k_\infty \rho}{\tau_0} t - \frac{S\tau_0}{k_\infty \rho} \quad . \quad . \quad (9)$$

and for a finite system,

$$n = \left[\frac{S\tau_0}{k_{ex}} + n_0\right] \text{exp.} \frac{k_{ex}}{\tau_0} t - \frac{S\tau_0}{k_{ex}} \quad . \quad (10)$$

Equations (5) and (6) are easily obtainable from (9) and (10) respectively, by putting $S = 0$.

Now, when the flux becomes steady,

$\frac{dn}{dt} = 0$ and equation (7) gives

$$S = -\frac{k_\infty \rho}{\tau_0} n, \text{ or } S = -\frac{k_{ex}}{\tau_0} n \text{ for a finite system} \quad . \quad (11)$$

which implies a negative value for ρ and hence k_{ex}, since S, τ_0, n, k_e and k_∞ are essentially positive quantities. At steady flux, then, we see that both excess k and reactivity must be negative.

Furthermore, when the reactor becomes critical, $k_e = 1$, so that $k_{ex} = \rho = 0$, and consequently in the steady condition the reactor is always very slightly subcritical.

We may further write equation (11) in the form

$$n=-\frac{\tau_0}{k_\infty \rho}S \quad \text{or,} \quad n=-\frac{\tau_0}{k_{ex}}S \qquad . \qquad . \qquad . \qquad (12)$$

Whence we see that in the steady subcritical state, the reactor acts as a simple amplifier of the source, the amplification factor tending to infinity as criticality is approached.

Now let us consider delayed neutrons when S is zero. Delayed neutrons are released by the decay of fission products as shown in the following example:

$$Br^{87} \xrightarrow[\text{(delayed)}]{\beta} Kr^{87} \xrightarrow{\gamma} Kr^{87} \longrightarrow$$
$$\downarrow n$$
$$Kr_{as} \text{ (stable)}$$

There are six groups of delayed neutrons with uranium. The production equation becomes:

$$\frac{dn}{dt}=\text{Prompt Prodn. Rate}+\text{Delayed Prodn. Rate}-\text{Leakage Rate}-\text{Absorption Rate}$$

Let c=fraction of delayed neutrons (0·0064 for natural uranium)

then $1-c$=prompt fraction of neutrons

If r_1=density of nuclei capable of producing delayed neutrons of type j

T_1=mean life of type j delayed neutrons

r_1=mean life of type j delayed neutrons

then rate of production of type j delayed neutrons $=\frac{r_1}{\tau_1}$

and total rate of production of delayed neutrons $=\sum_{j=1}^{6}\frac{r_1}{\tau_1}$

Prompt production rate $=n\nu\Sigma_a k_\infty (1-c)$

Absorption rate $=n\nu\Sigma_a$

Leakage rate $=n\nu\Sigma_a L_e$

$$\therefore \frac{dn}{dt}=n\nu\Sigma_a\left[k_\infty(1-c)-(1+L_e)\right]+\sum_{j=1}^{6}\frac{r_1}{\tau_1} \qquad . \qquad . \qquad (13)$$

whence $\frac{dn}{dt}=\underbrace{\frac{n}{\tau_0}k_\infty(\rho-c)}_{\text{prompt}}+\underbrace{\sum_{j=1}^{6}\frac{r_1}{\tau_1}}_{\text{delayed}}$

Now, $n\nu\Sigma_a k_\infty$=rate of production of neutrons in fission

$n\nu\Sigma_a k_\infty c$=rate of production of delayed neutrons in fission

$n\nu\Sigma_a k_\infty c\mu_1$=rate of production of type j delayed neutrons in fission

$$\therefore \frac{dr_1}{dt}=n\nu\Sigma_a k_\infty c\mu_1-\frac{r_1}{\tau_1}$$

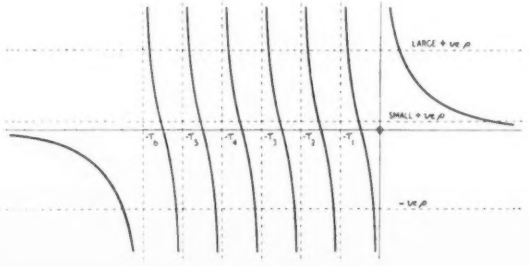


Fig. 2. ρ as a function of Ts

$$i.e., \quad \frac{dr_1}{dt}=\frac{nk_\infty c\mu_1}{\tau_0}-\frac{r_1}{\tau_1} \qquad . \qquad . \qquad . \qquad . \qquad (14)$$

There is one equation (14) for each of the six delayed neutron emitters and the neutron kinetics are thus governed by the seven linear, first order, differential equations (13) and (14).

The values of τ_1 and μ_1 for uranium fuel are given in Table 1.

Now let us assume that $n=A\exp.\frac{t}{T_s}$ . . (15)

and $r_1=B_1\exp.\frac{t}{T_s}$. . . (16)

Then substitution in equation (13) gives:

$$\frac{A}{T_s}=\frac{Ak_\infty(\rho-c)}{\tau_0}+\sum_{j=1}^{6}\frac{B_1}{\tau_1}$$

Similarly equation (14) gives

$$\frac{B_1}{T_s}=\frac{k_\infty c\mu_1 A}{\tau_0}-\frac{B_1}{\tau_1}$$

Hence, $B_1\left[\frac{1}{T_s}+\frac{1}{\tau_1}\right]=\frac{k_\infty c\mu_1 A}{\tau_0}$

and substituting for B_1

$$\frac{1}{T_s}=\frac{k_\infty(\rho-c)}{\tau_0}+\sum_{j=1}^{6}\frac{k_\infty c\mu_1}{\tau_0}\cdot\frac{T_s}{T_s+\tau_1}$$

therefore $\rho=c+\frac{\tau_0}{k_\infty T_s}-c\sum_{j=1}^{6}\frac{\mu_1 T_s}{T_s+\tau_1}$

$$i.e., \quad \rho=\frac{\tau_0}{k_\infty T_s}+c\left\{\frac{\mu_1\tau_1}{T_s+\tau_1}\ldots+\frac{\mu_6\tau_6}{T_s+\tau_6}\right\} \qquad . \qquad . \qquad (17)$$

since $\mu_1+\mu_2+\ldots+\mu_6=1$

This equation (17) is a polynomial equation of the seventh degree in T_s whose roots depend on the value of ρ. If these roots are $T_{s_1}, T_{s_2}, \ldots . T_{s_7}$, then the solutions of equations (13) and (14) are:

$$n=\sum_{i=1}^{7}A_i\exp.\frac{t}{T_{si}} \qquad . \qquad . \qquad . \qquad . \qquad (18)$$

$$r_1=\sum_{i=1}^{7}B_{1_i}\exp.\frac{t}{T_{si}},\ j=1 \text{ to } 6 \qquad . \qquad . \qquad (19)$$

in which the constants A_i and B_{1i} depend upon the initial conditions. The solution of equation (17) is most easily obtained by plotting ρ as a function of T_s as in Fig. 2; for any value of ρ the value of T_s can then be read off.

In the case of a finite system equation (17) reduces to:

$$\rho=\frac{\tau_0}{k_e T_s}+c\left\{\frac{\mu_1\tau_1}{T_s+\tau_1}\ldots+\frac{\mu_6\tau_6}{T_s+\tau_6}\right\}$$

and remembering that $k_e=\frac{1}{1-\rho}$

from equation (3), we get finally:

$$\rho=\frac{\tau_0}{T_s+\tau_0}=\frac{cT_s}{T_s+\tau_0}\left\{\frac{\mu_1\tau_1}{T_s+\tau_1}+\ldots+\frac{\mu_6\tau_6}{T_s+\tau_6}\right\}.$$

The neutrons present in a reactor arise in two ways: (*a*) prompt neutrons, which are emitted at the instant of fission; (*b*) delayed neutrons. These arise when a fission product undergoes radioactive decay to a daughter product which then emits a neutron. The rate of supply of such neutrons thus depends upon the yield of the fission product (or "delayed neutron emitter") and its radioactive decay constant (reciprocal of " mean life.").

TABLE I
Delayed Groups as Represented in the Reactor Simulator

Fuel	Group No.	Mean Life (sec) τ_i	Relative Abund-ance μ_i	Absolute Group yield, per cent.	Decay Constant λ_i (sec^{-1})	Chosen τ_i (sec)
U233	1	79·37	0·086	0·057	0·0126	80
	2	29·67	0·299	0·197	0·0337	30
	3	7·194	0·252	0·166	0·139	8
	4	3·077	0·278	0·184	0·325	3·25
	5	0·885	0·051	0·034	1·13	0·880
	6	0·4	0·034	0·022	2·5	0·350
U235	1	80·65	0·033	0·052	0·0124	80
	2	32·79	0·219	0·346	0·0305	30
	3	0·009	0·196	0·310	0·111	8
	4	3·322	0·395	0·624	0·301	3·25
	5	0·885	0·115	0·182	1·13	0·880
	6	0·333	0·042	0·066	3·00	0·350
Pu239	1	78·13	0·035	0·021	0·0128	80
	2	33·22	0·298	0·182	0·0301	30
	3	8·065	0·211	0·129	0·124	8
	4	3·077	0·326	0·199	0·325	3·25
	5	0·8929	0·068	0·052	1·12	0·880
	6	0·3717	0·044	0·027	2·69	0·350
U235/2	1	13·04	1·000	1·58	0·07714	13·28

The above figures are the latest available as published in the Reactor Physics Constants ANL-5800.

Only a small number of fission products have this property of giving rise to delayed neutrons; six are in fact known to exist. Their relative proportions depend upon the fissile fuel, and the proportions represented in the simulator are shown in Table I.

It is the delayed neutrons which largely determine the characteristic dynamic behaviour of a reactor when power changes are made. The proportions of delayed neutrons in the reactor only correspond to the relative yields in fission when the reactor is in the steady state, *i.e.*, densities of prompt and delayed neutrons are constant.

From the kinetic equations, we then have:

$$\frac{dr_i}{dt}=0$$

and then equation (14) shows that:

$$r_i=nk_\infty \frac{\tau_i}{\tau_0} c\mu_i$$

Let us now disturb this steady state, say by adding suddenly some negative reactivity.

The prompt neutron density will immediately fall, producing a prompt fall in power.

The delayed neutron density will, however, suffer no such sudden change, since it depends upon the fission products which were present before the disturbance. These will gradually decay until a new steady state is reached, in which the fission products, and hence the delayed neutrons, are again in equilibrium with the prompt neutrons.

The power change will, therefore, take place in two stages: (*a*) a prompt change, followed by (*b*) a steady change representable as a series of exponentials.

It may be shown that, provided the prompt mean life τ_0 is very much smaller than the smallest τ_i the prompt power change is given by:

$$\frac{n^1}{n}=\frac{c}{c-\rho}$$

where n^1 is the power level just after the prompt change and n is the steady power before the disturbance.

If we disturb the steady state by suddenly adding a small amount of positive reactivity, we similarly get a prompt rise given by the above formula, followed by a series of exponentials from the delayed neutrons. It will be observed that as the added reactivity approaches the value of c, the total delayed neutron fraction, the prompt rise increases indefinitely; the condition $\rho=c$ is referred to as " prompt criticality."

For values of ρ less than c, we obtain a prompt rise followed by exponential divergence; for values of ρ greater than c, the power rises indefinitely and extremely rapidly.

To sum up, we may picture the effect of delayed neutrons by observing that their density variations, and thus their contributions to the power, lag behind the power changes; when power has just been increased or is increasing, there are too few delayed neutrons for equilibrium, while when power has just been decreased, or is decreasing, there are too many of them for equilibrium.

Thus in bringing a reactor up to power from shut-down, when the desired power level is reached, the reactivity has to be kept slightly positive so that the excess of prompt neutrons compensates for the lack of delayed neutrons. As the delayed neutrons build up, the excess reactivity is gradually reduced to zero. Conversely, when a reactor has just been shut down, the exponentially decreasing power comes mainly from the delayed neutrons derived from the fission products present immediately before shut-down. If, during this exponential decrease, we make the reactivity less negative, by adding a little positive reactivity, the prompt neutrons produced added to the large proportion of delayed neutrons present will give a positive value of $\frac{dn}{dt}$. The power will therefore rise, but only for a short time, as the steady diminution in delayed neutrons will soon overcome the effect and the power will again fall.

In reactors moderated by heavy water or beryllium, additional delayed neutrons, known as photo-neutrons, are produced by the action of gamma radiations from fission products on the nuclei of deuterium or beryllium. Some of these photo-neutron producers have long mean lives, and high-flux, heavy water moderated, enriched uranium fuelled reactors take several hours to shut down completely.

Fast reactor

In a fast reactor, the mean lifetime of a neutron, from emission to absorption, is of the order 10^{-7} sec compared with about 10^{-3} sec in a thermal reactor. Although these lives differ by a factor of 10,000, they are both so short compared to the mean lives of the delayed neutron emitters that the difference in kinetics is noticeable only when the power is changing rapidly, or when step changes in reactivity are made. The doubling times of a fast reactor and a thermal reactor are virtually the same for values of reactivity less than about 0·1 per cent.+ The difference increases with reactivity until, when the reactors are prompt supercritical, at, say, +1·0 per cent., the doubling time of the fast reactor is about 10^{-4} times that of the thermal reactor.

Equation (12) shows that the steady power level of a reactor is proportional to the source strength, that is, to the rate of supply of neutrons from sources other than fission capture.

One source of such neutrons is spontaneous fission, mainly in U238. This, however, is very small, so that to obtain an appreciable power level from this source alone, the reactivity would have to approach very closely to zero. Thus start-up would be a dangerous procedure; moreover, to reach full power would take a long time unless the doubling time were made dangerously short. It is, therefore, customary to maintain a measurable shut-down power level by placing additional neutron sources in the reactor core. Three types of source are in common use, depending upon the type of reactor. Antimony-beryllium sources are suitable for high-power thermal reactors, where the thermal neutron flux is high enough to maintain the gamma activity of the antimony. Radium-beryllium sources are suitable for fast reactors and low-power thermal reactors. For research reactors where little shielding is required, polonium-beryllium sources are used because of the very small amount of gamma activity present. This latter type of source, however, has a short life of about three months.

This article will be continued next month

Letter to the Editor

Pinkerton Founder Award Paper

SIR: In connection with my paper, "Electric Power from Nuclear Heat—Direct," read for me at the Institution by Dr. Grassam and published in the June issue of NUCLEAR ENERGY, it has been suggested that a little more explanation about direct conversion applied to nuclear fusion would be welcomed. Accordingly, I would add that in a thermonuclear reactor the fusion process would occur in a highly ionized plasma, oscillations in which would constitute an alternating current, which could in principle be appropriately transformed for power generation. Since magnetic fields are essential to confine the hot, fusing plasma, the latter, when taken through a compression-expansion cycle, does work on the confining field in a way analoguous to the gas in an internal-combustion engine working against a piston. The point of my last sentence was that in solving the problem of confining the plasma we may incidentally solve the problem of extracting its energy directly as electric power. These possibilities have been discussed in some detail by Jukes (Proc. I.E.E., Vol. 106, Part A, Supp. No. 2, 1959).

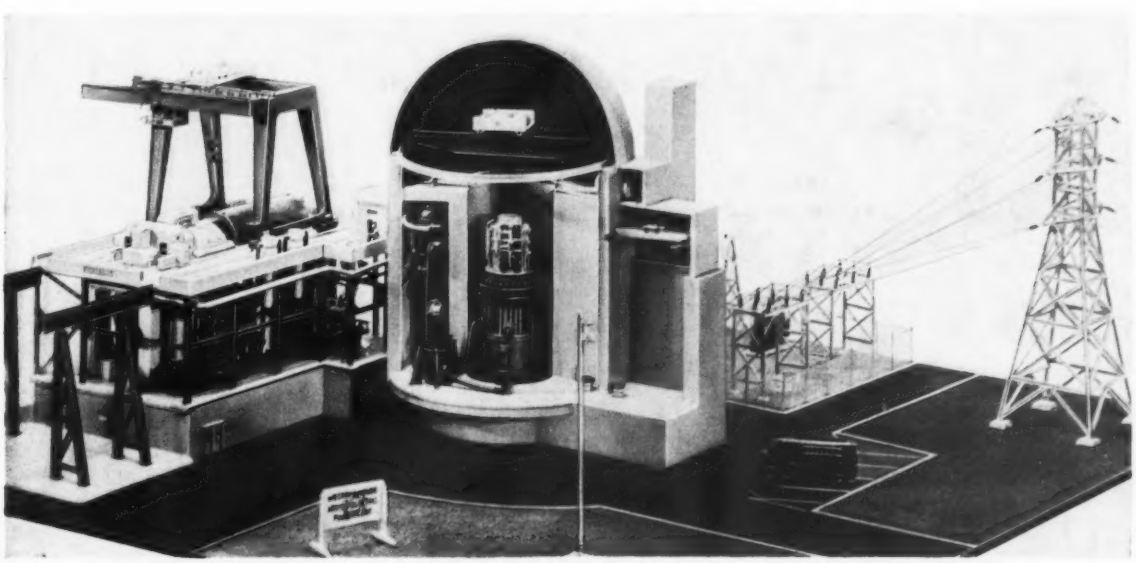
Yours, etc.,
J. W. GARDNER.

Whetstone, Leicestershire.

Presented to The Institution

This plastic model has been presented to The Institution by the manufacturers, Revell (Great Britain), Ltd.; it represents a power station embodying a pressurised water type reactor similar to those designed and built by Westinghouse Electric Corporation for the Yankee Atomic Electric Company, at Rowe, Massachusetts, and for a Belgian utility group near Mol, Belgium.

The model is made up from a construction kit of 237 separate parts, all of which are numbered for easy identification. Each part is broken from the bar as required, excess plastic being trimmed off, and assembled with a special polystyrene cement. The scale of the model is $^1/_{16}$ in. = 1 ft.



NUCLEAR NOTES

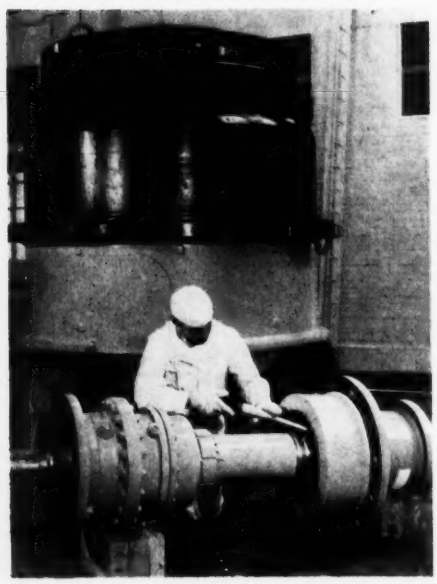
Essential power

A NEW simplified system has been developed by the UKAEA for the automatic starting of diesel engines to supply essential power to reactors in case of emergencies. The device consists mainly of a single valve controlling the admission of compressed air to the engine. This valve is opened by a falling weight which is held suspended by an energized solenoid until an electrical power failure occurs. When the engine has started oil pressure in the main lubricating system shuts the valve and at the same time latches the operating weight in the original position. Emergency generating engines at Dounreay and on the AGR at Windscale have been fitted with this device, and it is also being included in some of the nuclear power stations which the CEGB is constructing.

Euratom contract

EFFECTS of radiation on plants, conservation of foodstuffs by irradiation and the behaviour of isotopes in soil are the subject of a research programme to be carried out under a contract signed recently by the Institute for the Application of Atomic Energy in Agriculture at Wageningen, Netherlands, and Euratom.

Preparing part of a gas circulator for assembly under nuclear clean conditions. The dome in which the shaft is housed is seen in the background



Bilbao-Ebro

CENTRALES Nucleares del Norte, of Spain, has applied for authorization to set up a nuclear power plant at Valle de Tobalina, in the province of Burgos. The plant —to be known as Bilbao-Ebro—will cost about 3,140m. pesetas, 1,815m. pesetas of which will represent foreign exchange cost. The plant's capacity will be 250,000 kW and annual production will be 1,750m. kWh, with an 80 per cent. load factor.

New reactor

THE Australian Atomic Energy Commission is stated to be well on its way to achieving its goal of designing a new type of nuclear reactor for the production of electrical energy. Commission chairman, Professor Baxter, has stated that the Commission was now convinced it could build a high-temperature reactor using beryllium as the fuel element. He continued to say that seven years ago the Commission had set its sights on a beryllium reactor as opposed to the conventional graphite and heavy water reactors. One of the reasons being that beryllium was plentiful in Australia. Professor Baxter said he was confident that another four or five years' study would lead to the designing of the new type of reactor for generating electricity.

German budget

WESTERN Germany's 1961 budget provides for £24,636,000 to be spent on the peaceful use of nuclear energy, as compared to £21,045,000 in the previous year. The sum includes £8,127,000 earmarked as West German contributions to international atomic agencies and organizations. The largest part—£6,545,000, comprising £1,090,000 for administrative work and £5,455,000 for research and investments—will go to Euratom.

Cracow reactor

DESIGNS for the third Polish atomic reactor are being prepared at the Cracow Institute of Nuclear Physics by a team led by Professor J. Janik and should be ready this month. The reactor will be built during the present Five-year Plan, and its thermal power will be about 1 MW. It will be used for fundamental research in low energy nuclear physics, to meet the needs of industry in Southern Poland, in biological and agricultural research.

Dacca centre

ACCORDING to Pakistan's Minister for Fuel, Power and Natural Resources, the Pakistan Atomic Energy Commission will establish an atomic energy centre at Dacca for the training of personnel from universities, agricultural and medical colleges in the use of radioisotopes. The centre will be equipped with a powerful atom accelerating machine and will also have a research centre for agricultural problems of East Pakistan.

Dutch forum

A NUMBER of Dutch industrial concerns and the Netherlands Reactor Centre have taken the first steps towards the establishment of an organization to be called the Netherlands Atom Forum. The Forum will represent the Netherlands in the "Forum Atomique Européen," established in Paris on July 12th, 1960.

Indian station

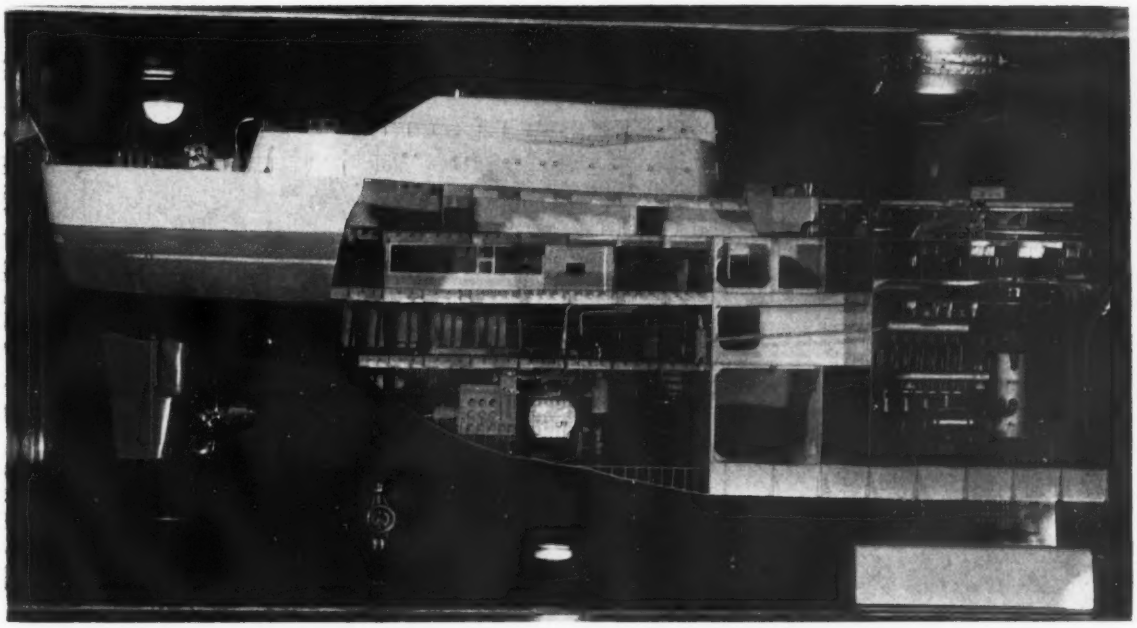
INDIA is to spend £38¼m. on the establishment of the first atomic power station at Tarapur.

Calder training

JAPANESE engineers who will hold senior posts in the Tokai Mura nuclear power station are receiving intensive training at Calder Hall nuclear power station. Tokai power station is at present under construction by GEC and will have a net power of 158 MW. Training of the Japanese engineers has been especially designed to suit the conditions which will be experienced at Tokai. The course includes a period at the Calder Operation School.

U.S.S.R. agreement

COLLABORATION on the peaceful uses of atomic energy was the subject of an agreement signed in London recently between the U.S.S.R. State Committee of the Council of Ministers for the Utilization of Atomic Energy and the UKAEA. The agreement provides for collaboration, exchange of information and visits in the following fields: nuclear physics, solid state physics, basic radiation chemistry, inorganic chemistry of elements of importance in nuclear science and technology, research on isotopes and research on the application of isotopes, plasma physics, high energy physics, reactor physics, and experimental fast reactors.



Oxford research

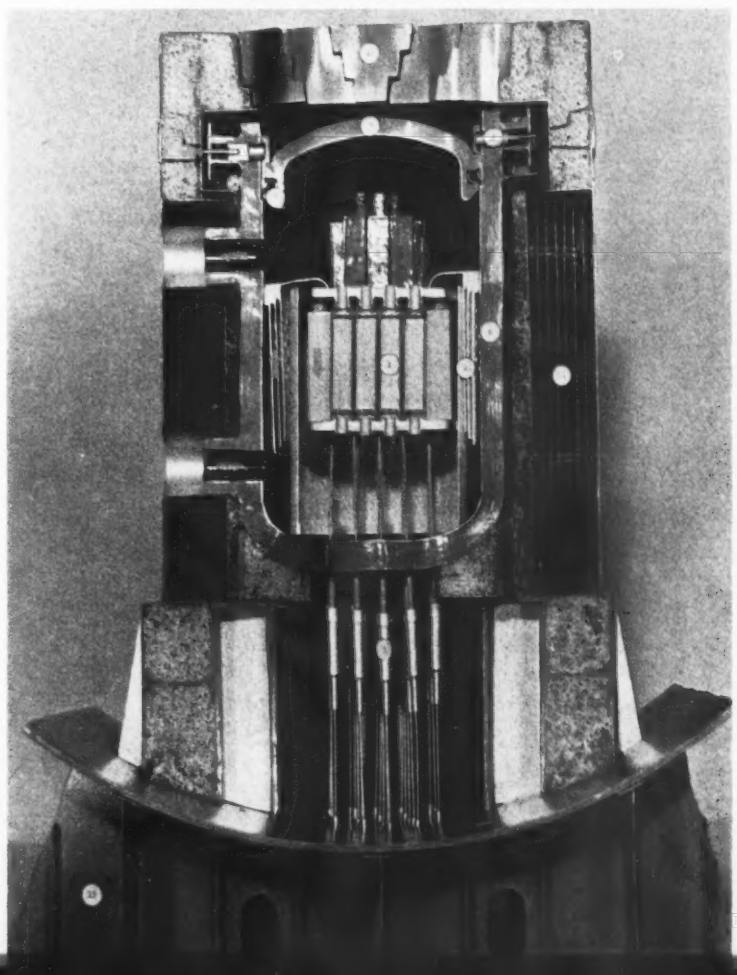
A NEW nuclear physics research centre is to be built at Oxford University. The Department of Scientific and Industrial Research is to contribute £750,932 towards the project, which will be led by Professor D. Wilkinson. Under the research programme a particle accelerator of novel design will be provided for long-term research on nuclear structure. Total Government support for the project will be in the region of £1m. The special equipment will consist of an 8-10 MeV vertical Van de Graaf generator which will be coupled to a 12 MeV horizontal tandem Van de Graaf generator. The vertical machine can be used either as a high-intensity generator or a high-energy injector in conjunction with the 12 MeV horizontal machine to give a combined energy of 20 MeV, with which experiments can be carried out throughout the whole range of nuclei.

Brazilian agreement

AN agreement has recently been concluded for co-operation between the European Atomic Energy Community and the Government of the United States of Brazil. Mutual aid and assistance in the development and use of atomic energy for peaceful purposes is the subject of the agreement. It proposes co-operation in the following fields: the exchange of information as regards research and development, health protection, installations and equipment and the use of ores, source materials, special fissile materials, sub-licences for patents, the exchange of students, technicians and teachers, the improvement of ore prospecting techniques, the construction of installations and equipment, the supply of ores, source materials, special fissile materials and radioisotopes, the processing of ores and source materials and the chemical treatment of fuels.

Japanese Ship

Hitachi Shipbuilding & Engineering Co. of Osaka, one of the leading Japanese shipbuilding and engineering firms, is conducting detailed research into the problems involved in the construction of a 65,000 d.w.t. tanker equipped with a nuclear reactor and a 25,000 s.h.p. turbine. A model of the ship is shown above, and of the propulsion unit below. The main details are as follows: length 237 m; breadth 34 m; depth 17·4 m; deadweight 65,000 l.t.; main engine, turbine (25,000 s.h.p.) 1 set; sea speed 17 knots



PEOPLE

K. J. Durrands

E. W. Herrington

J. W. Gardner

DR. GARDNER, one of the joint winners of the Pinkerton Founder Award for 1960, is a graduate of London and Birmingham Universities. Apart from the war years, when he worked on operational research for the RAF, his professional career has been wholly in theoretical physics. Since 1956 he has been with the English Electric Company's atomic power division, applying his subject to longer term reactor development. Previously he held appointments at Harwell, Chalk River, Sydney University and the Dublin Institute for Advanced Studies.

MR. K. J. DURRANDS, who lectured recently at the first meeting of the Midland Branch was educated at King's School, Grantham and then served a five years' Ministry of Supply engineering apprenticeship at the Royal Ordnance Factory, Nottingham, during which time he received part-time education at Nottingham Technical College. In 1952 he entered the Graduate School of Thermodynamics and Related Studies in the University of Birmingham and was awarded a Graduate Diploma in 1954. From 1954 to 1958 he was a technical engineer in the UKAEA at the Industrial Group Headquarters, Risley, after which he was seconded to the University of Birmingham to lecture in nuclear engineering to the Reactor Graduate School in the mechanical engineering department. He is an associate member of the Institution of Mechanical Engineers and received an MSc for his research on the pressure drop along a gas cooled nuclear reactor channel. He is shortly rejoining the reactor technology branch of the UKAEA.

DR. W. WILD has been appointed head of the chemistry division at Harwell in succession to **DR. SPENCE.** Dr. Wild will be responsible for the three branches concerned with chemical processing and reactor chemistry, radiation chemistry and solid state chemistry and radiochemistry. Born in 1907, Dr. Wild graduated from Leeds in 1928. He joined the chemistry division in 1947.

MR. A. A. SMALES, head of the analytical chemistry branch at Harwell has been given the status of a division head and will in future be responsible to the director. Born in 1916, Mr. Smales graduated from London in 1941. He then joined ICI at Billingham and was sent to Oak Ridge during the war to work on urgent analytical problems encountered in the electromagnetic separation plant. He joined the AERE at Harwell in 1947.

The appointment has been announced of **MR. L. WALKER** as company chief inspector for the Plessey Group of Companies. Mr. Walker previously held a similar position with Scottish Aviation, Ltd.

Two CERN scientists, **PHILIPPE DENNERY and ROBERT MEUNIER,** both from France have been sent to the Institute for Theoretical and Experimental Physics in Moscow. They will stay there for about two months, the former will work on field theory problems and the latter on the 7 GeV synchro-phasotron which is being built at the Institute.

M. E. ROSNER has resigned his post as senior lecturer in Mechanical Engineering at the Hendon Technical College and has now been appointed head of the mechanical and production engineering department of the Mid-Essex Technical College at Chelmsford.

E. G. Irwin and Partners, Ltd. have announced the appointment of **MR. E. W. HERRINGTON** as engineer in charge of the mechanical and electrical service department of their industrial division. Mr. Herrington was with the Ministry of Works from 1925 until 1958 when he joined the Turriff Construction Company, Ltd. While at the Ministry of Works Mr. Herrington was concerned with the development and construction of the principal atomic research establishments until the UKAEA was set up in 1954.

MR. T. MORRISON has been appointed group field sales manager, U.K., by The Solartron Electronic Group. Since joining the group Mr. Morrison has been regional sales manager, Southern England and sales manager for Solartron Laboratories, Ltd. He was a member of the team which went to the U.S.A. in 1956 to set up Solartron, Inc.

DR. D. O. CALDWELL has gone to CERN under a National Science Foundation Senior Postdoctoral Fellowship. Dr. Caldwell has recently been carrying out experiments with the 3 BeV Cosmotron at Brookhaven. At CERN Dr. Caldwell will be concerned with the 28 GeV particle accelerator.

MR. J. H. THORNTON has been appointed group resident superintendent for Sizewell nuclear power station by the English Electric, Babcock & Wilcox, Taylor Woodrow atomic power group. From December, 1957 until December, 1959 Mr. Thornton was chief civil engineer in the group resident superintendent's department at Hinkley Point. Since December 1959 he has been assistant group resident superintendent at Hinkley.

J. W. RYDE, the chief scientist at the GEC's Hirst Research Centre at Wembley, has died recently at the age of 63. Mr. Ryde was associated with the research laboratories of the General Electric Co. for most of his life. During the Second World War he made considerable scientific contributions to the nation's war effort.

D. J. OTT is to be manager of the new applied science division of the Internuclear Company. Mr. Ott has been senior nuclear physicist of the company's Consulting Engineering staff assigned to the Societa Electronuclear Nazionale project for a 180 (e) MW nuclear power plant.

DR. PIERRE LOUIS BALLIGAND has succeeded **DR. HUBERT DE LABOULAYE** as deputy director general in charge of the department of technical operations of the IAEA. Dr. Balligand was previously head of the large research reactor division of the French Commissariat à l'Energie Atomique. Dr de Laboulaye has returned to a senior position with the French Commissariat à l'Energie Atomique.

The death has been announced of **MR. W. H. APTHORPE,** deputy chairman and former managing director of the Cambridge Instrument Company, Ltd. Mr Apthorpe joined the company in 1900 and has been concerned with the development of many instruments, including the Duddell oscillograph and the Galitzin seismograph.

DR. W. H. ARNOLD has joined the staff of Nuclear Utility Services, Inc. as director of nuclear fuel management. Dr. Arnold has previously been with the Westinghouse atomic power division and was associated with the design of several American reactors.

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Slow neutron detector

A new slow neutron detector NE 421 of Li6F is now available from Nuclear Enterprises (G.B.), Ltd. The new detector makes use of the fact that the alpha particle emitted from Li6 after neutron capture has a higher energy than the corresponding alpha from boron-10, and this leads to considerably higher detection efficiencies in the scintillator. Detection efficiencies of up to 60 per cent. can be obtained with thermal neutrons, which is approximately double that obtained with B10 detectors. **(JUL 1)**

Fuel element tester

20th Century, Electronics Ltd. have now introduced an instrument for testing fuel elements.

The instrument consists of a mass spectrometer leak detector and an auxiliary pumping unit which is connected to an enclosure for testing single fuel elements.

The fuel element is internally filled with helium at reduced pressure and then loaded into the enclosure which is evacuated to a pressure of 10^{-5}mm Hg using the auxiliary pumping system. The enclosure is isolated from the pumping system for a period and is then connected to the mass spectrometer leak detector tuned to the helium peak to measure the pressure rise over a period of time.

A calibrated leak is supplied for adjusting the instrument. The complete operation for one element takes ten minutes. The pumping system is capable of sampling volumes up to 300 litres, and the unit can be attached to manifolds of testing enclosures for batch production. Both laboratory and batch-testing requirements are met by this unit. **(JUL 2)**

Counter shields

A new series of shields for manual and automatic counting is now available from Tracerlab of the U.S.A. The new series features a single universal top shield which can be interchanged between the Tracerlab SC-101, two position manual changer and the SC-104, three position manual flow counter. The same shield is also used as the top shield for the new Tracerlab SC-100 automatic sample changer. Principal features of the shield are ease of changeability and handling, and ability to accommodate a wide variety of detectors which can be changed at a moment's notice. **(JUL 3)**

Flow counter

Tracerlab have announced a new series of geiger-proportional flow counters. These are available in two sizes, the FD-1, 1 in. and the FD-2, 2 in. flow counters for operation in either the geiger or the proportional regions and with or without windows.

The new series of multi-purpose flow counters is of unique plug-in construction, operates with a wide variety of counting modes and a number of different flow gases. The FD-1 and FD-2 feature all plastic construction to minimize background and deposited stainless steel cathodes. The counters operate in the geiger region with standard Tracerlab G-1 gas or in the proportional region with argon-methane gas, pure methane or natural gas, and require no change of centre wire in changing from GM to proportional counting.

Fuel element testing instrument by 20th Century Electronics

An extremely thin window, less than 125 microgram/sq.cm, is standard for both the 1 in. and 2 in. counters.

Backgrounds for the 1 in. counters in the standard Tracerlab shield are less than 12 counts/min and for the 2 in. less than 30 counts/min in the geiger region, with plateau lengths of 300v with slope less than 2 per cent./100v over the entire range. Geiger operating voltage is 1,450v $\pm$150v. Using natural gas, the counter operates proportionally at 4,700v with a background for beta counting less than 30 counts/min and plateau length of 1,000v, slope less than 2 per cent. **(JUL 4)**

Pellet sintering

Spembly, Ltd. have designed and manufactured a means of individually loading radioactive metallic pellets into a high temperature vacuum sintering furnace. The apparatus was designed for the UKAEA and consists of a loading unit and an automatic programming power unit.

A magazine is filled with 36 pellets inside a glove box and then transferred to the loading unit. The door of the inner end of the magazine is automatically opened and the loading unit which is mounted on to the end of the furnace is then sealed. The pressure within unit and furnace is reduced to 10^{-4}mm. of mercury and the temperature of the furnace allowed to rise.

When the correct temperature conditions have been established, the loading mechanism is put in motion by the automatic programming power unit. The pellets drop

Cut along here

To: NUCLEAR ENERGY
147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT & MATERIALS *feature for July, 1961*

Item No's ....
....

IS THIS ENQUIRY CONFIDENTIAL? YES | NO

Enquirer's Name .....
Position .....
Firm .....
Address .....

individually into a cup at the end of a long arm. The arm, which is provided with a water-cooled seal, is then pneumatically fed into the hot zone of the furnace and rotated to deposit the pellet. To avoid pellets piling up in the furnace an automatic "pushplate" is fitted to the end of the arm.

The pellets are deposited at regular predetermined intervals and are counted. The count and loading sequence are displayed on the programme unit. When all the pellets have been deposited in the furnace a warning bell sounds. If a fault develops during the sequence, *e.g.*, air-pressure failure with the long arm in the furnace hot zone, then the fault warning light comes up, another bell sounds and the arm is automatically withdrawn by means of air from the reservoir.

The mechanism is completely automatic. Once the magazine has been put into position and the vacuum and temperature conditions have been attained in the furnace the operator presses the "start" button and no further attention is required, until all the pellets have been loaded or a fault in the mechanism develops. At the end of the loading sequence, the programming unit remains active and after a predetermined period gives an indication that the complete heating cycle is at an end. **(JUL 5)**

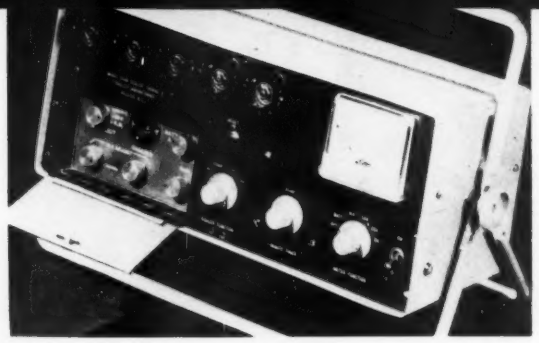
Soil condition

The TESTlab Corporation of Chicago, U.S.A. have recently introduced an improved system for determining per cent. moisture and density of soil by nuclear methods. This equipment, while adaptable to a wide range of uses, finds its largest demand in compaction control and study of soil moisture and density conditions prior to highway and dam construction. It also finds wide usage in moisture studies relative to water conservation, agricultural and irrigation control projects.

The complete system comprises a counting unit (sealer) and a moisture and/or a density probe containing a radioactive material and a detector system. Measurements are made by inserting or placing the probe on the material being tested and making a reading on the portable scaler.

Principally this system allows at least 5 to 10 tests to be run in the same period of time required to run one conventional test. Human errors are virtually eliminated and many areas not accessible to conventional methods can be tested.

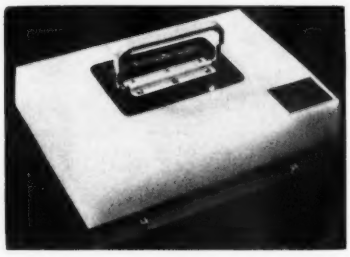
The equipment is heavier than usual but it is safer as only low activity sources are used. **(JUL 6)**

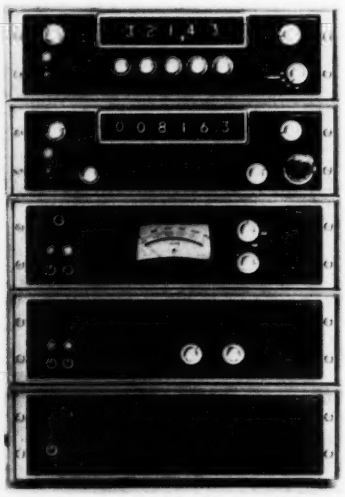


(*Above*) **Portable sealer by Testlab Corporation for determining per cent. moisture and density of soil**

(*Left*) **Testlab surface moisture adapter**

(*Below*) **Testlab depth moisture probe**





The four chassis of the Nuclear Chicago Logic 802

Integrated counting

Nuclear-Chicago have announced a new integrated proportional counting system, the Logic 802. The system consists of four chassis in a single unit to provide linear amplification, scaling, timing and high voltage for GM counting or for proportional and scintillation counting with integral pulse-height analysis. A cooling base with forced air flow and a separate preamplifier are supplied with the system.

Elapsed time and accumulated count data is continuously presented by means of in-line numerical readout. A gain of 50,000 and positive pulse output to the scaler is furnished by the linear amplifier. Continuous attenuation is provided to a factor of 512. Double delay line differentiation is incorporated to prevent base line distortion at high input rates.

The linear amplifier and an adjustable discriminator for positive pulses in the scaler permit both proportional counting and integral pulse-height analysis. Preset count is provided with ranges from 100 to 10^6 counts.

Complete present time selection is available for all displayed increments of the timer. Preset time, preset count, or time-count may be used to stop counting.

A digital recorder, a linear ratemeter, a logarithmic ratemeter and a graphic recorder can all be connected. **(JUL 7)**

Electronic modulator

Designed and manufactured by Bailey Meters & Controls and marketed by the Telephone Manufacturing Co., Ltd. is the electronic modulator SM 10, the first fully encapsulated transistorized chopper.

It is a small, highly stable, silicon transistorized chopper designed for low level d.c. chopping. Of the directly coupled type the SM 10 offers the simplest form of clamp-type chopper with which to solve circuit problems. The chopper has a built-in wave shaping circuit and will operate from any 6v sinusoidal or square wave supply from 40 c/s to 1,000 c/s, and will switch a range of chopping voltages from 1 micro volt to 250 milli volts.

Since all the components are encapsulated within an aluminium can, the unit is virtually immune from vibration and shock effects. The SM 10 has no moving parts to suffer wear or contacts to become contaminated and it never needs adjustment. **(JUL 8)**

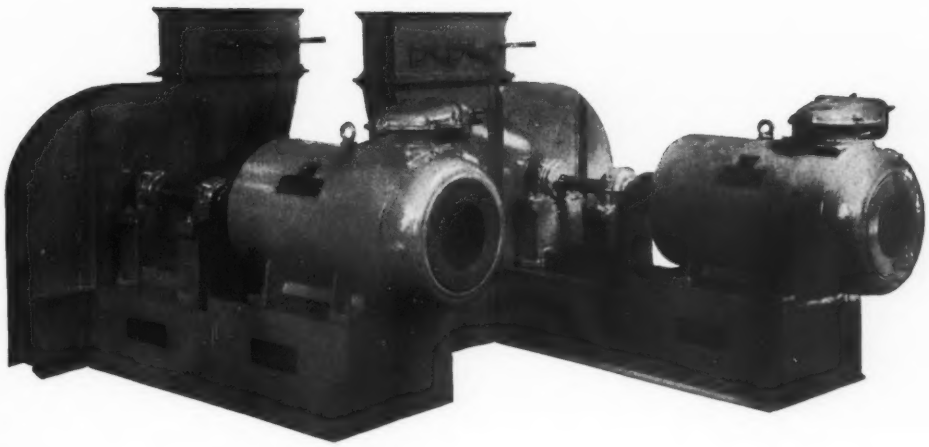
Detector pulses

By means of pulse transformers, Plessey Nucleonics, Ltd. have recently solved the problem of transmitting small amplitude pulses from nuclear radiation detectors over long lengths of cable, without having to use a head amplifier.

Long lengths of cable, generally located a considerable distance from the main pulse amplifier, reduce the voltage amplitude of the charge pulse at the amplifier input grid. But by using pulse transformers to match the cable this difficulty has been overcome since the coaxial cable now behaves as a transmission line. This reduces the loss in pulse height to that due to the normal r.f. attenuation in the cable.

The pulse transformers are used in pairs, one being fitted to the detector and the other to the head amplifier. Thus long lengths of cable can be used without appreciable attenuation of the original signal or limitation of the counter performance. **(JUL 9)**

*"IMPULSITOR" FANS



Two No. 27 "Impulsitor" "N" type backward curved multivane Fans, for handling explosive gases at an Oil Refinery. Both are for vertical up delivery, one for anti-clockwise, one for clockwise rotation. Duty:—7,000 C.F.M. 30 in. Bar. at 27 in. T.W.G. when running at 2,900 revs. per minute each direct coupled, through flanged couplings to a 50 H.P. totally enclosed flame-proof Motor, Buxton certified for use with Group 2 Gases. The Motor and Bearing Platform is fabricated from steel plate and is of welded construction.

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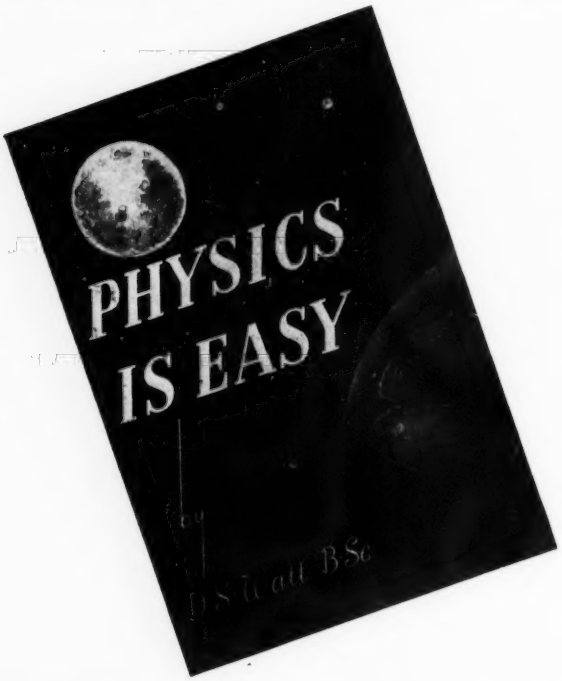

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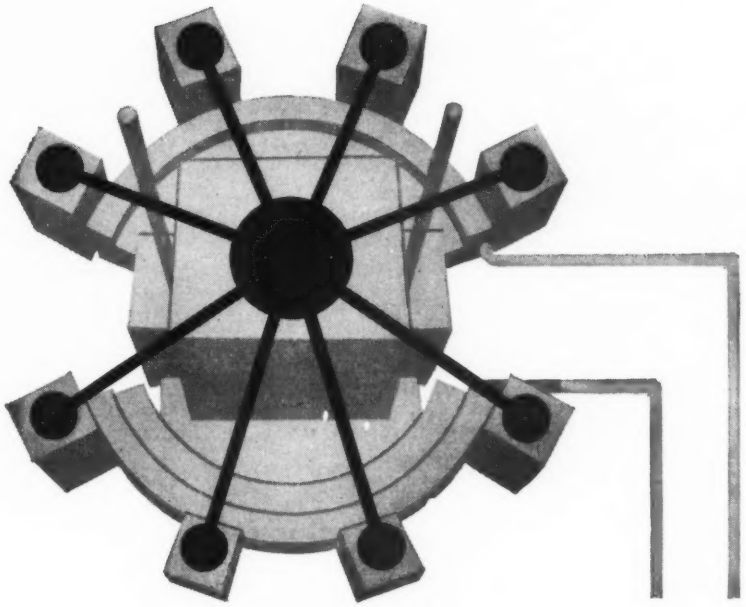

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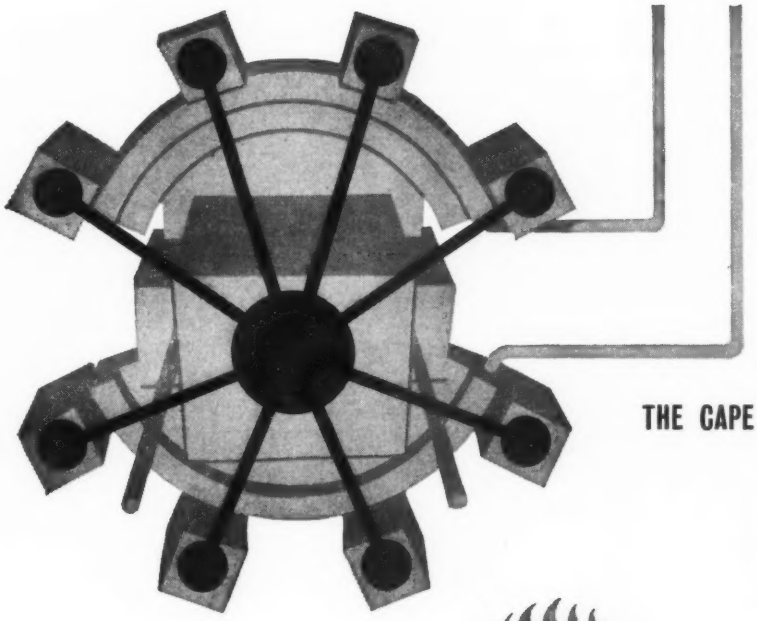

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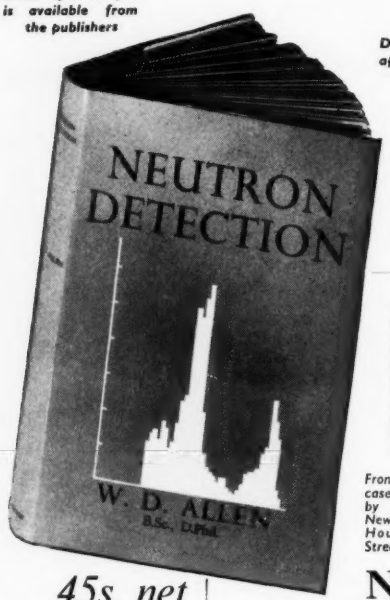

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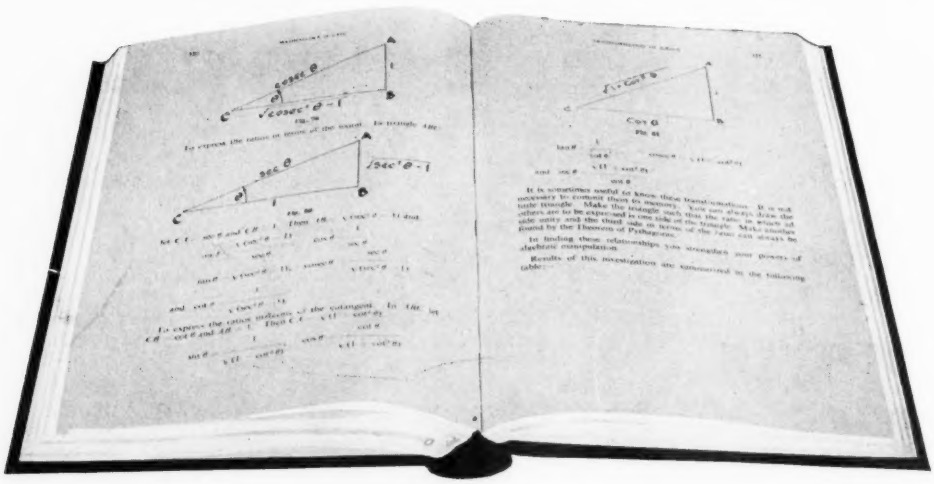

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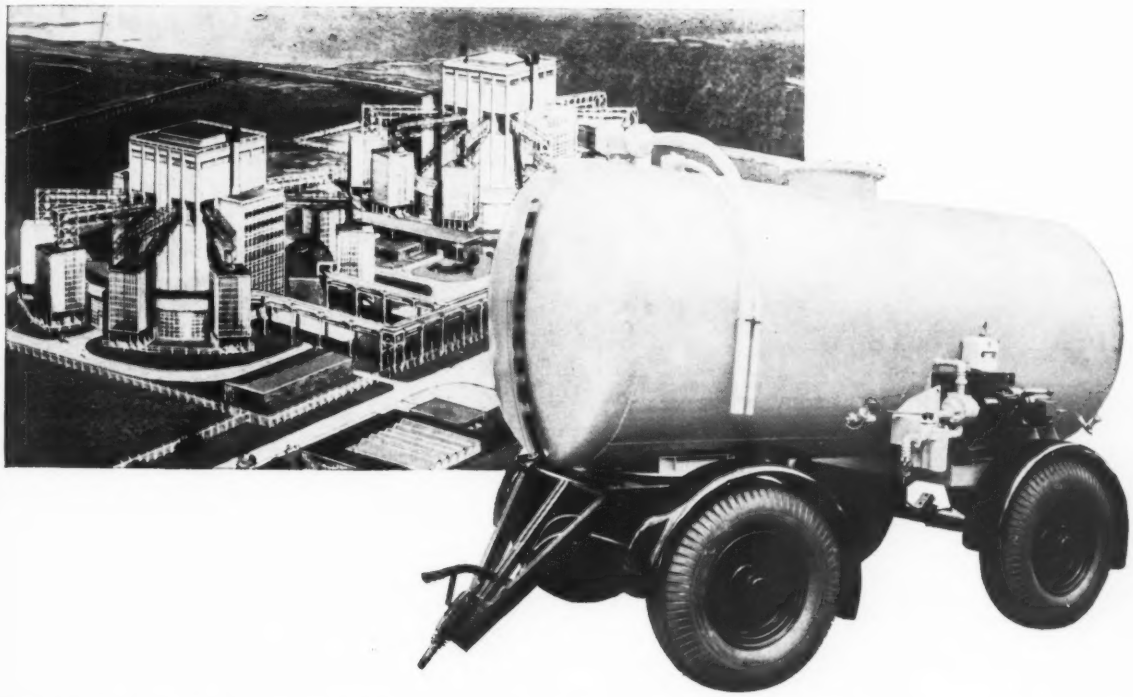

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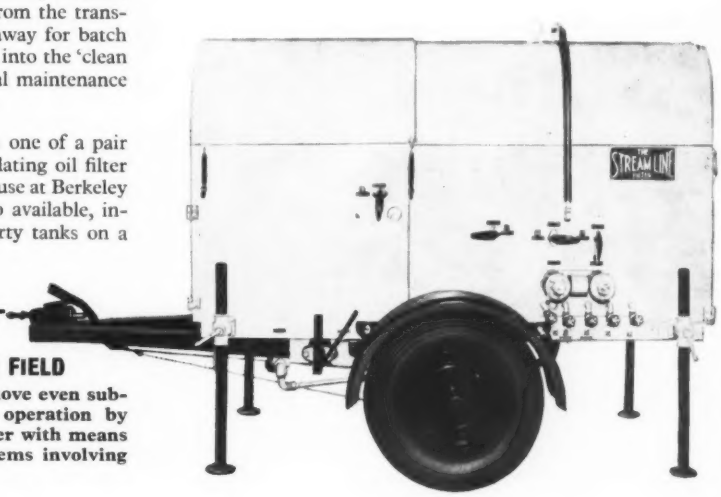

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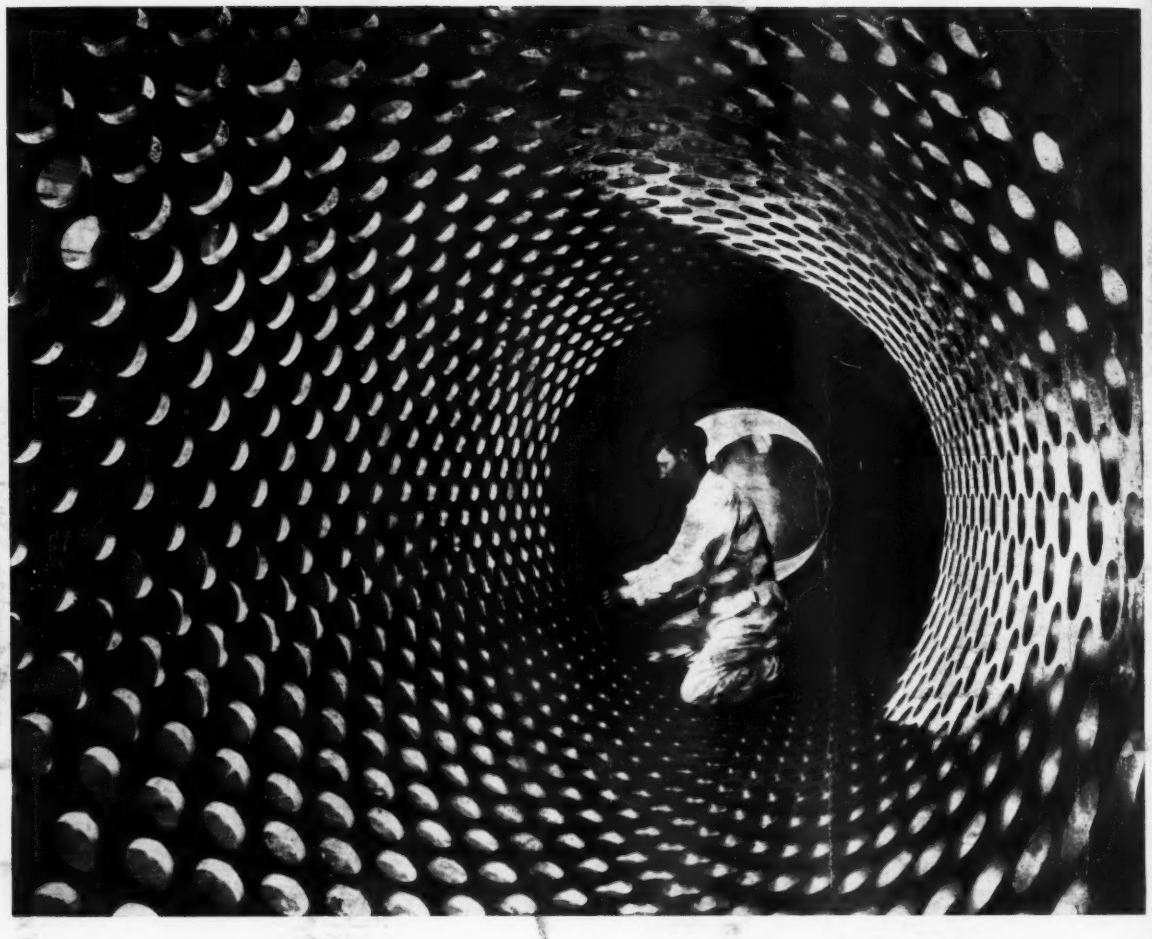

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